EXTRA-PLEURAL PNEUMOTHORAX IN THE TREATMENT OF PULMONARY TUBERCULOSIS.

A Medical Analysis of the Short-term results in a Series of One Hundred Consecutive Cases.

John Guthrie Stevenson, M.B., Ch.B., F.R.F.P.S.G.,
Senior Registrar, (Tuberculosis),
Thoracic Unit,
Mearnskirk Hospital,
Newton Mearns,
Renfrewshire.

February, 1952.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 – 1346

I N D E X

* * * * * * *

PREFACE

Despite the great advances made during the past six years in the antibiotic and chemotherapeutic attack on the tubercle bacillus, the main adjuvants to the bed-rest treatment of pulmonary tuberculosis are still the various medical and surgical collapse measures employed to bring rest and relaxation directly to the diseased lung tissue. There can be little doubt that the most effective therapeutic answer to the tuberculous invasion will be supplied by some future potent antibiotic which can quickly eradicate the infection before avascularity renders the lesion inaccessible and structural changes necessitate more radical intervention. Streptomycin and para-aminosalicylic acid show the miraculous potentialities of drug therapy, but still go only part of the way towards this ideal. Caseation and fibrosis obstruct their action and the destructive end-results of the tuberculous process still demand more radical measures.

The search for a safe method of selective, reversible collapse of the tuberculous lung has long been the obsession of physician and surgeon alike throughout the world. As early as 1891, Tuffier was experimenting with extra-pleural mobilisation of the lung as a candidate for this high ideal and since that time published opinion regarding the operation has ranged from glowing enthusiasm to almost complete despair. The encouraging reports came early, but widespread use brought

disillusionment in the form of disastrous complications and fatalities caused by infection of the extra-pleural space and spread of tuberculous disease.

The decision to re-introduce the operation on a large scale at Mearnskirk Hospital was taken early in 1950. There was no intention of supplanting the operation of thoracoplasty, which still remained the treatment of choice in chronic excavated phthisis. But for every case deemed suitable for such radical surgery, there were several with lesions more immature in type who could quite conceivably benefit from a less drastic and possibly reversible form of collapse in the shape of extra-pleural pneumothorax. The popularity of artificial intra-pleural pneumothorax was decidedly on the wane and collapse of the diseased lung was becoming largely surgical. Under the protective umbrella of streptomycin, resections of the tuberculous lung or lobe were being embarked upon with greatly increased safety and if anything the pre-antibiotic antecedents of those operations were even less encouraging than those of extra-pleural pneumothorax.

There was complete awareness of the distressing sequelae previously attendant upon the operation of pneumonolysis but with streptomycin, penicillin and para-aminosalicylic acid as powerful advantages over earlier workers in the field, it was thought that the incidence of these complications could be considerably reduced. The first operation was accordingly

performed on 2nd February, 1950. During the three months that followed, only nine patients were treated but early obvious evidence of success in the way of cavity closure, sputum conversion, etc. were soon forthcoming and thereafter the tempo rapidly increased. By 12th April, 1951 a total of 105 operations had been carried out in 100 patients and it is with the medical assessment of the value of extra-pleural pneumothorax in the treatment of the tuberculous infection in these patients that this paper is concerned.

The survey involved has several unique features. It is, as far as the writer is aware, the first published large scale revaluation of extra-pleural pneumothorax performed under the cover of streptomycin. The series described by Cutler (1951) is the nearest approach to it in the literature, but only approximately half of his 129 cases had the benefit of the antibiotics. Frequent comparison with this surgeon's results is made throughout the chapters which follow. In addition, all the operations involved were performed within the space of fourteen and a half months - an unusually condensed period by comparison with previous reports. Finally, all the operations were performed in one unit by two surgeons - Mr. R. S. Barclay, Consultant Surgeon to the Thoracic Unit, Mearnskirk Hospital, and Mr. T. M. Welsh, Surgical Registrar of the team. A very considerable proportion of the after-care of the patients from the earliest post-operative days onwards was entrusted to the author in his capacity as Senior

Registrar (Tuberculosis) attached to the unit.

I am indebted to Mr. Barclay whose continual enthusiasm and encouragement provided a stimulus for this work and to whom all credit is due for the re-introduction of this form of treatment in our part of the world. My thanks are also due to Dr. Douglas McIntyre of Mearnskirk Hospital for his invaluable assistance with the photographic reproduction of the illustrative skiagrams. Nor must I leave unstated the willing co-operation afforded me by the nursing staffs of the chest pavilions of Mearnskirk Hospital, who assisted me in the not inconsiderable serological and bacteriological work entailed in the follow-up of these cases.

* * * * * * *

CHAPTER ONE.

HISTORY.

Extra-pleural pneumonolysis is one of the oldest operations in thoracic surgery. As early as 1891, Tuffier was experimenting with mobilisation of the lung as a method of treating tuberculous disease of the upper lobe. His results with the operation were poor, for he made no attempt to fill the space he had formed and relied for the maintenance of the collapse on the haemorrhagic exudate which was the inevitable sequel of the intervention. The unfailing absorption of the exudate within the course of a few weeks produced little or no lasting benefit in the underlying lung. This unpromising debut was followed by a protracted phase characterised by diligent searchings for a suitable filling substance with which to maintain the collapse for the length of time necessary to have a beneficial effect on the tuberculous process in the lung.

In 1910 Tuffier was the first to perform pneumonolysis with permanent filling. For this first case he employed fresh human omentum removed from another patient the same day. In 1911 he utilised fresh lipoma tissue. By 1914 he could report 11 cases with fat plombage with one patient cured, three improved, three unchanged and four deaths. The first mention of air refills as a method of maintaining the collapse came from Mayer in 1913. This German surgeon, after deprecating

the use of the paraffin, lipiodol and vioform plombage just described by Baer in the same year, advised the use of air, stressing the advantages of ease of administration, exact dosage and lack of danger. Mayer experimented with the paraffin-lipiodol mixture in two animals and contrived to produce gangrene of the lung in one and a bronch-extrapleural fistula in the second. Despite his advice and his dire prognostications, air as a refilling medium was not exploited and attention was rather given to a motley collection of inert plombe materials. Alexander (1925) gives an imposing list of those substances in which the following are included - fresh or preserved omentum, subcutaneous fat, lipoma tissue, fibrosed tissue, muscle and bone fragments, pedicled grafts of muscle, breast and fat, inflated rubber gloves, masses of paraffin, 'Humanol' (a liquified human fat), gauze, etc. The disadvantages of the fatty tissues were the obvious ones of atrophy and loss of volume. Bone fragments with their sharp ends were prone to erode the lung and inflated bags were objectionable because of secondary infection.

The successful use of pedicled grafts of pectoralis major muscle, breast tissue and fat was described in 1924 by Morriston Davies. In a few female patients good results were achieved, but the operation was not practicable in males. Romanis and Sellors (1935) described their use of various materials over a 15 year experimental period. They found that the pectoralis major muscle was usually not voluminous

enough and in any case soon atrophied. Lipoma tissue they thought useful but it was rarely available. Air was too rapidly absorbed and gave rise to troublesome emphysema. Inflated rubber balloons gave excellent results but could not be left in place indefinitely as the rubber perished and the air leaked out. They thought that a paraffin wax, with a melting point of 55° Centigrade, was the best substance. On the Continent too, the paraffin plombe had long been in vogue. Sauerbruch (1937) described the use of this filling which he had employed since 1914. The mixture he used contained paraffin, bismuth carbonate and vioform and the results of the procedure were apparently good. Erosion of lung and cavities and shifting of the heavy plombe were the major disadvantages.

From this comparative stagnation, extra-pleural pneumonolysis was suddenly rescued in the middle nineteen thirties by the brilliant work of Graf of Dresden (1936) and Schmidt of Heidelberg (1938). Both these surgeons carried out the operation on a large scale, underlined the importance of skilled, energetic, post-operative management and advocated the use of air as a space filling agent. The success of their early results produced an international wave of enthusiasm. In this country, Roberts performed the first operation at the Brompton Hospital in 1937 and in rapid succession Brock (1938) and Sellors (1938) published their results. In America,

similar widespread use of the operation occurred. The enthusiasm of the initial successes, however, was soon damped when the grave tally of operative disasters and post-operative morbidity became known. By 1940 extra-pleural pneumothorax, both in this country and in America, was once more on the wane and from that date to the present time the British contributions to the literature on the subject could be counted on one hand. Those few reports emanated from Laird (1940), Reid (1946), Mullard (1948), and Roberts (1948). On the Continent interest in the operation was maintained. In France, Bérard (1948), Joly (1948), Garrand (1948) etc. continued with the operation. From Italy, Zorini published his results in 1949. Swiss contributions came from Arnold et al (1946), Brunner (1944) and Düggeli (1944). Seip (1950) and Murstad (1951) were Scandinavian contributors.

In America extra-pleural pneumonolysis was continued on a somewhat sporadic scale, but once again determined efforts were made to find a suitable inert filling agent. Ottaviano (1940) once more resorted to the paraffin pack. Wilson (1948) utilised a plastic resin - methyl methacrylate and in a small series of 15 patients, recorded some excellent results. Polyethylene was employed as a space-filling agent by Condon et al (1949). Hurst et al (1950) described the use of plastic sponges. The extra-fascial pneumonolysis which accompanies the Semb type thoracoplasty was reinforced by air refills by Aycock et al (1940). This extra-fascial variety of pneumo-

thorax was continued until adequate rib regeneration could keep the apex of the lung compressed. In Britain, Konstam (1948) described a similar technique and quoted the selectivity of the procedure, its vital capacity sparing effect and its bilateral application as the main advantages. These advantages are the very essence of extra-pleural pneumothorax and indeed the two operations differ only in the plane in which the pneumothorax is established.

The advent of the modern antibiotics has widely extended the horizons of surgery in the treatment of pulmonary tuberculosis. In the sphere of extra-pleural pneumothorax, large scale re-assessment of the operation seemed a valuable step. Early in February 1950 this present series was commenced at Mearnskirk Hospital and with growing evidence of success the operation came to be performed in the other thoracic centres of the area. Now, after the passage of almost two years, the total number of patients treated in this region is well above 500 and increasing steadily.

* * * * * * *

CHAPTER TWO.

INDICATIONS AND CONTRA-INDICATIONS FOR OPERATION.

I. INDICATIONS.

A. Introductory Observations.

With the re-introduction of extra-pleural pneumothorax two major problems required elucidation. The first, which concerned the safety of the procedure, is discussed later. The second, with which this chapter deals, was to discover the range of applicability of this form of treatment and to determine its strength and limitations. Reference to previous writers on the subject was not on the whole very inspiring. Their observations, summed up briefly, were that extra-pleural pneumothorax was justifiable only when thoracoplasty was rendered dangerous by reason of debility, bilateral involvement, low respiratory reserve or age. In other words, thoracoplasty's contra-indications were the indications for extra-pleural pneumothorax. The only further limited concession made to the operation was that its value in preparing the patient for ultimate thoracoplasty was accepted by several authorities. There was little or no attempt to accord the procedure a place in the treatment of pulmonary tuberculosis on its own merits.

This restricted attitude was the direct legacy of the poor results and desperate complications which had followed the intensive use of the operation in the late thirties and

early forties. As such a limited field of application afforded little help in allowing an extensive reassessment of extra-pleural pneumothorax it was decided to broaden widely the indications for treatment and include many patients hitherto considered unsuitable. The object was to define the place of the operation in a well-planned scheme of treatment for the tuberculous patient,and as a result a wide range of tuberculous pathology has been covered. At the acute end of the scale, exudative disease was excluded and for chronic irreversible changes the value of thoracoplasty was not contended. Between these limits extra-pleural pneumothorax has been widely applied. The finality of thoracoplasty was therefore reserved for those who had sustained irreversible pulmonary damage while extra-pleural pneumothorax was applied to those in the no man's land between unsuccessful conservative treatment and radical permanent surgery. The group of those unsuitable for thoracoplasty by reason of bilateral disease was continued, but this time with the object of using extra-pleural pneumothorax as a treatment in itself and not as a stop gap for better things to come.

The following indications therefore are the outcome of these investigations and represent the present day attitude to the applicability of the operation. It will be seen that there is little mention of thoracoplasty, for it is felt that extra-pleural pneumothorax has its own independent sphere of

activity. The artificial subdivision of indications into various categories such as the absolute, broad, and conditional groups of Dolley et al (1940) is of interest mainly in retrospective assessment of results and will be mentioned again under this heading. The question at the outset is really - 'Can this patient be assisted in some degree by extra-pleural pneumothorax?' If the answer, certain or probable, is in the affirmative, then operation is indicated. By ruthless selection it is possible to ensure the good results of most forms of treatment, but with such a lethal disease as tuberculosis it is unfair to deprive a patient of the benefit of operation because he contravenes a few regulations in the code of indications. Brock (1938) pertinently remarks that narrowing of the indications would eventually include patients who would do well without surgery.

B. Pathological Phase of Disease.

As has just been mentioned, extra-pleural pneumothorax in this series, has been dovetailed neatly into the logical plan of treatment of pulmonary tuberculosis by applying it to the patients who have shown an incomplete or partial response to the usual routine medical measures and who are as yet too immature by pathological standards for major, irreversible surgical intervention. In other words the essentially destructive nature of the early exudative phase of the infection has been reduced effectively by a combination of

such measures as bed-rest, streptomycin, para-aminosalicylic acid, phrenic crush and pneumoperitoneum. The average duration of disease in our patients, from the time of definitive radiological diagnosis to the time of operation, was two years and nine months. Despite the obvious fallacies in measuring disease age in this way, this figure does give some indication of the comparative maturity of the lesion. It is weighted somewhat unduly on the longer side by reason of the inclusion of several patients with histories extending up to 11 years, for whom there was no safe alternative form of treatment.

Evidence of the commencement of a reparative process in the diseased lung is afforded by a more definitive radiological outline and a concomitant reduction of moist physical signs. Transition to this more productive pathology ushers in the period during which extra-pleural pneumothorax is effectively and safely applicable. Logically this interplay of destruction and fibrosis continues with increasing accent on the latter until fibrosis predominates. When this occurs, the shrunken, rigid lung with its contained thick-walled cavities becomes the logical candidate for either thoracoplasty or operative removal. It is important to bear in mind that a lung or a portion thereof may be irrevocably destroyed by disease beyond the hope of rehabilitation by any form of therapy. (Churchill, 1940). To apply extra-pleural pneumothorax to such cases is to apply a potentially reversible

procedure to an irreversibly destroyed lung. The only excuse for so doing would be on occasions where bilateral involvement, age, etc. contra-indicated radical treatment. Such circumstances have arisen several times in our patients, and permanently destroyed lung tissue has been treated with some excellent short term results. The ultimate condition of the re-expanded lung remains to be seen but the immediate dramatic improvement in thse patients makes it a well worthwhile experiment.

Similarly extra-pleural pneumothorax is not a desirable procedure at the acute end of the scale. Surgical intervention in the toxic patient with actively spreading disease is fraught with considerable risk at any time and it is felt here that the great majority of these cases can be rapidly and safely prepared for surgery at a later date by the timely use of streptomycin. Cutler (1951) has operated on 18 patients with acute caseating tuberculosis, who were deteriorating steadily in spite of bed-rest. Many of them were desperately ill and there was little hope of stabilization of the disease to allow eventual surgery. Extra-pleural pneumothorax contrived to give a completely successful outcome in 13 (65 per cent) of these patients, was unsuccessful in four (20 per cent) and gave an overall mortality of three (15 per cent). These are truly gratifying figures and Cutler believes that some of the operation's most dramatic, life-saving results can be achieved

in this group. Most of these operations were carried out in the pre-antibiotic era, however, and the urgent necessity for intervention could probably be reduced nowadays by the use of streptomycin.

This application of extra-pleural pneumothorax by pathological standards, gives the operation an extremely wide scope. The patient who has unsuccessfully run the gamut of medical treatment is rarely ready by ideal pathological criteria to proceed immediately to thoracoplasty. By utilizing extra-pleural collapse logically during this period, the time spent in waiting for a satisfactory degree of fibrosis to appear can be reduced to a bare minimum and ultimate thoracoplasty can be readily avoided. It is in this sphere that pneumonolysis becomes a form of treatment in its own right rather than a stop gap process of substitution. Shorn almost entirely of its dangerous complications, it is a very valuable addition to the therapeutic armamentarium without in any way supplanting the other more widely accepted forms of treatment.

C. The Cavity.

(1) Cavitary Characteristics.

The prime objective of all treatment in pulmonary tuberculosis, be it medical or surgical, is to effect closure of the tuberculous excavations which develope in the diseased lungs. These cavities, with their chronically infected walls

and bacilliferous sputum, are the reservoirs from which chronic, low grade, or sometimes more acute spreads of disease, take place. In effect, they are the perpetuators of disease which go to make pulmonary tuberculosis, if left untreated, a chronic, progressive, illness with an ultimately fatal outcome. Surgical collapse measures, by occluding the drainage bronchus and bringing the cavitary walls into apposition, allow slow healing by fibrosis or calcification to take place. By firm splinting also of the diseased lung or lobe, the mild though continual disrupting forces of respiration are abolished and with this local application of rest the reparative processes can continue undisturbed. The definition, however, of the tuberculous cavity is somewhat loose and embraces all sizes of excavation, from the almost total lobar variety to the merest honeycombing perhaps only made obvious by closely spaced tomographic radiography. Technically a sputum containing tubercle bacilli indicates either active endobronchial disease or cavitation of some degree, large or minute, in communication with the bronchus. Tracheo-bronchial tuberculosis in the absence of active parenchymal involvement is comparatively rare and bacilli in the sputum for practical purposes, indicate a cavity whether it be radiologically obvious or not.

Every patient in this series showed radiological evidence of cavitation in the upper lobe, displayed by either postero-anterior radiography or tomography. The cavitary dimensions

ranged from a minor honeycombing appearance to total excavation of a lobe. In the latter category, the largest cavity encountered measured seven centimetres in its broadest diameter. Table No. 1. below sets out the respective dimensions and the numbers of each. Four centimetres have been taken as the arbitary standard of measurement to illustrate the range of cavitary dimensions.

TABLE NO.1.

Cavitary Size.	Numbers.
Up to 1 centimetre.	20
1 - 4 centimetres.	57
Over 4 centimetres.	28
TOTAL:	105

These dimensions were all recorded over the greatest diameter. In some instances a cavity system was present in which none of the cavities individually exceeded the four centimetre limit. The total area of excavation, however, in many cases was over this level and justified their inclusion in the over four centimetres class.

Several surgeons have commented on the unpleasant potentialities of the large cavities in contributing towards an increased incidence of serious space complications. The first danger, of course, is accidental tearing of the thin

pathological wall during the pneumonolysis. There can be little doubt that such cavities are more prone to disaster of this kind. The later disadvantages are tuberculous empyema of the space - not in itself a dangerous occurrence - and broncho-extrapleural fistula, which is the most lethal of all complications. In this series all sizes of cavities were treated and many good results were achieved both above and below the four centimetre line. Of the 28 operations (in 27 patients) performed for cavities or cavity systems greater than four centimetres in diameter, only 17 (60.7 per cent) spaces are still maintained with air. These have all given, without exception, excellent results. The rest have in the main been converted to either thoracoplasty or oleothorax. The thoracoplasty conversion rate in these patients is 17.8 per cent (five cases) and compares very unfavourably with the 3.9 per cent (three in 77 spaces) in the rest of the series. The main redeeming feature about this very marked difference is that two of these converted cases were initially unsuitable for thoracoplasty and were rendered much better risks for this operation by their brief extra-pleural collapse. Their cavities were reduced in size and more readily pinned against a more fixed mediastinum.

This large cavity group also yielded the one broncho-extrapleural fistula in the series, and contributed one tuberculous empyema (3.6 per cent) to the overall total of three. The additional two empyemas occurred in 77 further operations

(2.6 per cent). There is thus no great apparent disproportion in the empyema rate but the figures in any case are too small to allow a definitive comparison. It was felt however that the extreme cavity size amounting to almost total destruction of the upper lobe - seven centimetres in its broadest diameter in the patient in question - was a contributing factor to the subsequent empyema. The patient who ultimately developed the broncho-extrapleural fistula had a cavity diameter of six centimetres. With such very gross excavation, where the lateral and superior cavity walls consist of a mere rind of diseased lung parenchyma bolstered insecurely by the two pleural layers, surgical opinion now looks upon extra-pleural pneumothorax as a temporary, cavity-reducing procedure, to be replaced within a short time by thoracoplasty. The danger of primary thoracoplasty in these patients is that the cavity is all too frequently left as an unclosed vertical slit in the paravertebral gutter. The preliminary extra-pleural pneumothorax displaces it downwards, reduces its size dramatically and renders it much more amenable to later thoracoplastic attack.

The safe upper limit of cavity size for extra-pleural pneumothorax is probably in the vicinity of four to five centimetres. Beyond this, the cavity verges on total or substantial destruction of the upper lobe and although an extra-pleural collapse may sometimes be safe and sufficient to cope with it, it is wiser to avoid such cases or to employ

the operation as a purely temporizing measure. The question of the loosely named 'subpleural' cavity is considered later in connection with tuberculous empyema in the chapter describing complications. It may however be said that it would be extremely difficult to contain a cavity of any size in the upper lobe of the lung without its boundaries encroaching on the pleura at some part. The assessment of proximity to pleura by postero-anterior radiography is fallacious and fails to demonstrate the subpleural position of cavities which lie in the paravertebral gutter, anteriorly, or on the mediastinal aspect of the lung. Roberts (1948), realising this fallacy stressed merely that cavities which were adjudged to be subpleural by postero-anterior radiography alone had a worse prognosis than apparently central cavities. This is a more reasonable and more accurate statement of the position. Thickness of cavity wall is also frequently referred to by earlier writers as being an unfavourable prognostic factor.

On theoretical grounds, the somewhat brittle, over fibrotic wall of a superficially placed cavity would seem more prone to mechanical rupture under the positive pressure stresses of extra-pleural therapy. In practice this apparent disadvantage is not confirmed and several such cavities have been effectively compressed without ill effect. Cavities of this type, however, are more amenable to treatment by thoracoplasty in the absence of any contra-indicating factors.

They represent the end result of an irreversibly destructive process in the lung and are better treated by a permanent form of collapse.

(ii) Tension Cavity.

The cavity of potential tension type is amenable to the positive pressure collapse of extra-pleural pneumonolysis. The relaxation afforded by intra-pleural pneumothorax and artificial pneumoperitoneum merely superimpose a mechanical kinking effect on the already stenosed bronchus. The resultant dangerous ball-valve mechanism allows the entry of air into the cavity during forced inspiration and impedes its exit during the much weaker expiratory phase. The steady ballooning which results in these circumstances is not seen in extra-pleural therapy and the dire pleural and pulmonary complications which can supervene are avoided. The strongly positive space pressure effectively prevents a steady build up of air under tension in these cavities, which are as readily closed as those with freely draining bronchi. Reid (1946) has commented that tension cavities respond much better to extra-pleural pneumothorax than to thoracoplasty. The most menacing complications, however, are to be seen more frequently during the course of intra-pleural pneumothorax or artificial pneumoperitoneum treatment rather than after thoracoplasty. For the production of a satisfactory result with such cavities, it is essential that a tight standard extra-pleural pocket is achieved. An accidental tear of

the parietal pleura with the production of a combined intra-extrapleural space sets up the same conditions as apply in an ordinary intra-pleural pneumothorax. High positive pressures cannot be effectively and selectively brought to bear on the cavity. The tension mechanism is assisted rather than hindered and a steadily enlarging cavity is the result. This sequence of events occurred in one patient in this series - Case No.95. An accidental combined space led to aggravation of the cavity and in turn early abandonment of the extra-pleural collapse. The cavity was later controlled uneventfully by a two stage, six rib thoracoplasty.

(iii) 'Hilar' Cavities.

In our experience the notoriously resistant cavities in the apex of the lower lobe are not suitable for treatment by the standard extra-pleural operation. By reason of the limited selective extent of the pocket no effective compression of the dorsal lobe can be achieved. We have made no effort to include patients with dorsal lobe excavation in this series. One girl, Case No.91, besides having a huge right upper lobe cavity had co-existent excavation in the apex of the right lower lobe. In addition, some unstable infiltration was present in the left upper lobe. Extra-pleural pneumothorax was employed in the absence of any other more helpful kind of attack. Her upper lobe cavity has been closed but the fate of her dorsal lobe cavity remains uncertain. It has certainly dwindled in size and is no longer obvious in postero-anterior

radiography but probably persists on a diminished scale in the paravertebral gutter. Her sputum formerly strongly positive now no longer contains the tubercle bacillus and her B.S.R. has dwindled from 96 millimetres in the first hour (West.) to 24 millimetres. This girl has certainly been considerably benefited by the closure of her upper lobe cavity but the dubious fate of the dorsal lobe one does not encourage routine employment of extra-pleural pneumothorax for such cases. Cutler (1951), who carries out a more extensive mobilisation of the lung in its lower extremities and makes no attempt to mobilise the mediastinal aspect, records good results in this type of case. By the extensive contra-mediastinal compression which can be achieved he records a very satisfactory outcome in two out of four cases and helpful assistance in the other two. His illustrated x-rays of one patient show an extra-pleural space which extends to the diaphragm on the affected side. This very extensive compression has not been attempted at Mearnskirk and where possible, preference is rather given to resection as the treatment of choice for such cavities.

D. Site and Extent of Disease.

Extra-pleural pneumothorax is by and large a measure calculated to produce effective control of tuberculous disease in the upper zones of the lung. The lower limit of its effective sphere of action is probably in the vicinity of

the sixth rib posteriorly. Below this level adequate disease compression cannot be hoped for. Some improvement in the lower half may occur when the main, disease-perpetuating focus in the upper lobe is efficiently dealt with by extra-pleural pneumothorax. Scattered lower lobe infiltration therefore is not an absolute contra-indication. One or two surgeons, including Stoyko (1946), have briefly described the use of basal extra-pleural pneumothorax for lower lobe disease itself. He reports successful results in six out of eight cases and appears quite impressed by its efficacy. None of our patients have been treated in this manner and no comment is possible.

The treatment of bilateral disease by an extra-pleural pneumothorax on each side is a universal theme in all the literature and has been fully proved here. Five of our patients achieved arrest of their disease in this manner without any aftermath in the way of dyspnoea, etc. The highly selective action of the pneumothorax, spares the undiseased basal lung tissue on each side and leaves adequate respiratory reserve. Apart from bilateral upper stage thoracoplasty which is somewhat limited in its application, extra-pleural surgery stands alone as a safe method of treatment of bilateral disease. In the patients in this series, the contra-lateral lung was completely free of disease in 31 cases. A further 41 showed evidence of 'inactive' disease consisting either of fibrotic infiltration or calcification.

Twenty-eight patients had active contra-lateral disease with actual cavitation, ranging from minor honeycombing to five centimetre diameter excavations, or extensive unstable infiltration. None of these patients showed subsequent homo, or contra-lateral deterioration. Indeed many with active disease in the unoperated lung, showed improvement therein after operation on their more diseased side.

E. Age Groups.

Many authors have been very favourably impressed by the fact that extra-pleural pneumothorax may be utilised over a much wider age period than can thoracoplasty. Roberts (1943) writing in Grey Turner's textbook of Modern Operative Surgery states that patients between 30 and 40 years yield the best results from thoracoplasty. The operative hazards increase progressively after the age of 40, but good results can be obtained up to 60 years of age. He gives 20 as being the lower age limit. In practice, at least at Mearnskirk Hospital, thoracoplasty is rarely performed over the age of 50 years and 16 years is probably the lower limit. By comparison, Joly (1948) devoted an entire article to the very impressive results he achieved with extra-pleural pneumothorax in children between the ages of five and ten years. Of 22 cases operated on between 1942 and 1947, 18 (81 per cent) have had a completely successful result. He quoted a collection of figures from his surgical colleagues which show that 60 (83 per cent) were completely successful out of 71 cases.

Thoracoplasty is, of course, completely ruled out in these early age groups by reason of its destructive effect and subsequent interference with growth. Table No. 2. below shows the age distribution in this series. There were no children under ten years and the youngest was aged eleven.

TABLE NO.2.

AGE IN YEARS						
10-19	20-29	30-39	40-49	50-59	60 & over	Total
27	40	20	10	3	Nil	100

The age range was 11 years to 55 years and the age group with the maximum incidence was the 20 to 29 one which yielded 40 of the 100 patients. Eighty-seven patients fell between the 10 and 39 year limits. Only three patients exceeded the age of 50 but this was merely because patients in this age group are comparatively infrequent and no more presented for operation during the time of this series. Those older patients withstood the operation excellently without exception and there seems no reason why elderly tuberculous subjects should not be treated by extra-pleural surgery when other indications are satisfactory.

It is obvious therefore from these remarks that extra-pleural pneumothorax can be performed successfully and safely at both ends of the thoracoplasty age scale. This factor is of particular importance in children where conservation of the

thoracic cage is of paramount importance. If thoracoplasty is to be performed on these children, operation must be postponed until growth has at least slowed down. An age of 16-17 years is the very lowest one at which thoracoplasty can be performed without subsequent danger of considerable deformity. At the other extreme, the lung conservation properties of extra-pleural pneumothorax show to their full advantage in elderly tuberculous patients, who while not being good subjects for the multi-stage permanent collapse of a thoracoplasty, tolerate extra-pleural treatment remarkably well. Unlike thoracoplasty, the operative hazards of extra-pleural pneumothorax do not appear to increase with age.

F. Applicability in Poor General Condition.

The use of extra-pleural pneumothorax in patients in poor general condition and with a considerably reduced respiratory reserve is frequently mentioned by various authorities. The capacity of such patients to withstand this operation with comparative ease is remarked upon and the subsequent, substantial improvement in both disease and patient is often described. Most of the earlier writers, however, made use of this effect, mainly to prepare a patient for later thoracoplasty. The maintenance of the extra-pleural pocket, attended as it was by diverse complications, was not considered justifiable and as soon as the patient was reasonably fit more radical surgery was used. With modern drug therapy, and the very marked reduction in space complications which has resulted

from it, the pneumothorax can be safely continued and the improvement maintained without resort to further surgery.

No fewer than 22 (22 per cent) of our patients fell into the last resort class by reason of poor general condition, extensive nature of bilateral disease and poor respiratory reserve. The great majority of them have done extremely well and many of them have been returned to useful lives outside the hospital. Their outlook, prior to operation, was in every instance hopeless, each case being apparently destined to a progressive and ultimately fatal illness. Gross cavities have been closed, sputum rendered persistently negative for the first time in the course of the disease, and general condition dramatically improved. The following Case report illustrates what can be done in those cases.

Clinical Case Report. Case No.7.

The patient, a married man of 39 years, with a bad family history of tuberculosis, was first admitted to Mearnskirk Hospital in October 1949 for assessment for surgical intervention. He gave a long history of chronic bronchitis with recurrent asthmatic incidents extending back to early childhood, with pneumonic illnesses at the age of four, 12, 17 and 30 years. His tuberculous disease had been discovered a year prior to admission but had probably preceded diagnosis by an indefinite time - the symptoms being inextricably intermingled with those of his chronic bronchitis. His only previous treatment had been a period of several months bed-rest

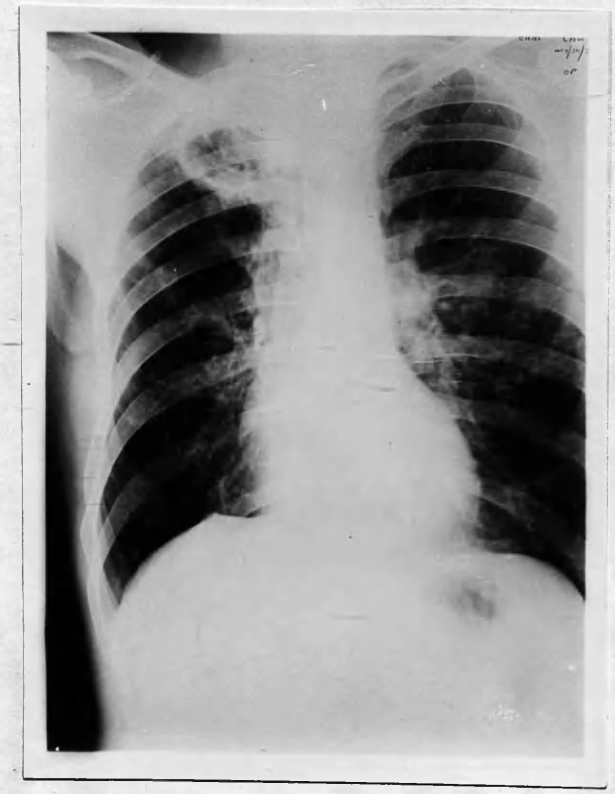


Fig.1.

in another hospital. His general condition was poor. He was thin, pale-faced and toxic with a persistent, troublesome cough. A directly positive sputum was obtained and the B.S.R. was 25 millimetres in the first hour (West.). An x-ray of his chest revealed a 3.5 centimetre extreme apical cavity in the right lung with scattered deposits of unstable disease as far down as the third interspace. The left lung, apart from some emphysematous changes, was clear. Auscultation revealed numerous rhonchi throughout both lung fields, with frequent coarse, sticky crepitations over the right upper lobe. At this time extra-pleural pneumothorax was not being performed at Mearnskirk and thoracoplasty was deemed out of the question because of cavity site, general condition and bronchitic background. He was retained for 10 weeks during which time an active spread to the left mid-zone occurred and completely vetoed the question of surgery. Transfer back to his parent hospital was duly arranged. In early March 1950 he returned to us for assessment for extra-pleural pneumothorax treatment which had been just commenced. His clinical and radiological state had not altered, no antibiotics having been given. Fig.1. opposite shows his radiological appearances. Combined streptomycin and P.A.S. therapy was commenced and by early April 1950 some resolution was noted in the left lung. A right extra-pleural pneumothorax was performed on 20.4.'50 and despite a pleural tear which resulted in a temporary combined space and a somewhat stormy bronchitic post-operative course,

Fig.2.

an excellent result was achieved. He was duly returned to his original hospital and ultimately dismissed on 14.7.'50. In October 1950 he restarted work as a garage handyman and has continued this employment ever since without incident.

When reviewed in October 1951 he was in very good general condition. His weight was 9 stones 6½ pounds;his B.S.R. was four millimetres in the first hour (West.) and his sputum negative for the tubercle bacillus by direct smear and culture. He was working effortlessly full time and attended his clinic for refills every fortnight. His vital capacity which was 2,200 cubic centimetres before operation had risen to 2,400 cubic centimetres. Fig.2. shows his latest radiological picture. An excellent tight extra-pleural space exists with the upper lobe disease adequately compressed and in part calcified. The left mid zone spread has cleared entirely.

Thus this man's actively spreading tuberculous disease has been effectively arrested. His pneumothorax has been safely maintained for 18 months up to the time of review and commencing healing of his disease by calcification is already manifest.

The routine pre-operative assessment of patients in this series has included a vital capacity estimation. In some of those poor risk patients the reading may be extremely low and apparently incompatible with further safe reduction if surgical collapse is carried out. Indeed one girl of 17 years,

Case No. 98, with gross bilateral disease and bilateral five centimetre cavitation could only muster 1,050 cubic centimetres before her first extra-pleural was performed. In her post-operative course some cyanosis was obvious but no dyspnoea occurred. Seven months later her second extra-pleural operation was carried out with a pre-operative vital capacity figure of 900 cubic centimetres. Again no dyspnoea resulted and she now has effective bilateral disease control without any respiratory distress. Vital capacity estimations are, of course, notoriously approximate and inaccurate. Some education in the use of the apparatus in an intelligent patient can steadily increase the readings obtained by several hundred cubic centimetres. The best estimate of respiratory function can be obtained by clinical observation of the patient's respiratory movements and his response to moderate exercise. Cutler (1951) echoes these remarks by saying - "The best guide in my experience, has been the clinical impression of the patient." Murstad (1951) agrees that observation is the best means of assessing cardio-respiratory function in those poor risk cases but uses vital capacity measurements as a crude yardstick. The borderline at which to exclude some of those patients from operation is difficult to define. The safety of extra-pleural pneumothorax, its freedom from shock and its selective, limited action on the diseased lung all contribute to make the range of applicability very wide indeed. Breathlessness at rest or

on slight to moderate exertion, should exclude the most dangerous cases. Thereafter, selection rests with individual assessment of the patient, his disease, his temperament and his prognosis if left untreated. Only increasing experience with the operation can afford a reliable guide. It is as well to remember however that "From the patient's point of view, it is better to live with a cavity than die without one." (Semb, 1937).

G. Miscellaneous Indications.

The effective use of extra-pleural pneumothorax in the treatment of a case of silico-tuberculosis is described by Maier (1946). The resistance of this dangerous combination of diseases to other forms of treatment is mentioned. Cutler (1951) describes the application of extra-pleural surgery in open tuberculosis complicated by pregnancy. He considers it a very useful answer to this difficult problem. Friedman et al (1949) reports that 30.8 per cent of the hundred and four cases in his series, had the operation performed at the patient's own request. This astonishing figure, he attributes to favourable newspaper propaganda, fear of major surgery and the desire for a satisfactory cosmetic result in women. It is conceded that when extra-pleural pneumothorax is successfully performed on a large scale in a thoracic surgical unit as it has been at Mearnskirk, the morale of the patients is remarkably high. They quickly realise all the attractive facets of extra-pleural surgery and of course compare it very

favourably with the more mutilating procedure of thoracoplasty. They readily acquiesce to the operation, but if told that thoracoplasty is the more desirable form of treatment, as quite a few have been told, there is no remonstration and the surgeon's opinion is accepted. There have thus been no personal request operations among our patients and in the light of our experience Friedman's figures are astounding.

2. CONTRA-INDICATIONS.

The contra-indications for extra-pleural pneumothorax when dangerous complications are at a premium, are relatively few. They have already been briefly referred to in the preceding pages. The optimum pathological phase has been described and the extremes of pathology, exudative and unduly fibrotic disease should be avoided. Tuberculous involvement of the lower lobe cannot be improved and excessive peripheral cavitation of the upper lobe is potentially dangerous. Poor cardio-respiratory capacity, assessed in the manner described, should exclude interference. Within these limits, extra-pleural pneumothorax is a safe and frequently dramatically effective procedure.

* * * * * * *

CHAPTER THREE.

I. PRE-OPERATIVE MANAGEMENT.

In the preceding chapter, an account has been given of the various criteria which qualify a patient for extra-pleural pneumothorax. The pathological phase of the disease suitable for operation has been outlined and in brief, it has been shown that the fibrosing but not over fibrotic lesion is the prime indication for treatment. This implies, of course, that the initially destructive characteristics of the infection have, to some extent at least, been subdued by the application of the appropriate medical sanatorium measures. It is during this time that diligent efforts are made to control the disease by every means short of surgery. During the last 20 years the range of conservative medical measures at the disposal of the chest physician has slowly increased, and today with the intelligent use of bed-rest, artificial pneumothorax and pneumoperitoneum, phrenic crush etc., an ever increasing number of patients make a satisfactory recovery from the tuberculous infection unaided by major surgical intervention. In the past five years, with the added dramatic assistance of the antibiotic and chemotherapeutic remedies, streptomycin and the salts of para-aminosalicylic acid, these numbers have increased still further. Later in this chapter, a fuller mention is made of these powerful tuberculo-specific remedies because of

their supreme importance in the management of the patient undergoing extra-pleural pneumothorax treatment. But their value in the operative period is second only to their value in the routine sanatorium treatment of the disease.

Thus before any patient is even considered for surgical treatment he has run the gamut of a series of medical measures which may procure the arrest of his disease at any stage. Extra-pleural pneumothorax is never considered as a form of primary treatment and is reserved for those who fail to respond either in whole or in part to the more simple forms of therapy. Even, however, if failure, in terms of disease control, is the outcome of this period, many patients still derive important material benefit. This benefit is evidenced by improved general condition, reduced cavity size, resolution of contra-lateral disease and transition of disease to a more productive phase. In brief, the time they have spent in sanatorium has served as an excellent method of pre-operative preparation. In addition, in another category entirely, should be mentioned the patients who at the commencement of their illness appear totally unsuited for any form of surgical treatment but who after efficient sanatorium measures may be converted quite dramatically to reasonable operative risks. The methods producing these results are worthy of some fuller consideration.

A. Bed-rest.

In those preliminary months the patient is subjected to any one or a combination of the measures mentioned above. Bed-rest, despite the power and range of many recent methods, remains the sheet anchor of treatment. Ideally, such rest to achieve its maximum therapeutic benefit should be carried out in sanatorium. In this series of cases, drawn as it is very largely from Glasgow and its environs where the waiting list for sanatorium admission is substantial, such an ideal was not always possible. As a substitute modified bed-rest at home had to suffice and by co-operation with the medical staffs of the town's clinics, an endeavour was made to admit the outpatient for surgery when a satisfactory clinical and pathological state had been achieved. The majority, however, of our patients were drawn from sanatorium wards at Mearnskirk or one of a number of other sanatoria, including Ruchill Hospital, Law Hospital, Lochmaben Sanatorium or the isolation hospitals of Stirlingshire. By one method or another every patient under consideration had been subjected to a period of bed-rest, and this period in turn, in practically every case, was studded by one or more of the various ancillary medical measures deemed applicable to the disease. Over the whole series, the average time which elapsed, between definitive radiological diagnosis of the disease and operation, was two years and nine months. It

is realised that this method of estimating the age of the lesion is basically inaccurate but to some extent the figure does illustrate the comparative maturity of the tuberculous process in the patient chosen for operation. The longest time-lag was 11 years and the shortest, five months. The former period occurred in two cases in which extra-pleural surgery was deemed the only possible treatment left for the patient. They both fell into the "conditional group" described by Dolley et al (1940) and mentioned in the previous chapter. In no way could they be taken as representing the cases ideally suited for the operation. There were several patients with the shorter pre-operative phase, but in them it was obvious from radiological appearances that the commencement of the disease had considerably ante-dated diagnosis.

B. 'Medical' Collapse Measures.

Under this heading come artificial pneumothorax, phrenic nerve interruption, and artificial pneumoperitoneum. These supplementary measures have each a fairly well defined field of application in the treatment of pulmonary tuberculosis. In the last 10 years the efficacy of artificial pneumothorax has come seriously into doubt, largely because of the very grave complications which may attend its widespread use. In the 1930's, it had become

so popular by reasons of its deceptive simplicity that it came to be applied to a very wide range of tuberculous lesions for which it was in many ways unsuited. Grave pleural and pulmonary complications became increasingly evident and gradually, especially in some centres, it fell into almost complete disuse. It has been referred to as the most dangerous quasi-surgical treatment in pulmonary tuberculosis. Hayes (1949) circularised a questionnaire regarding its use to 90 leading American chest physicians. From the analysis of the replies he received, he recorded that 13 physicians out of 70 giving definitive answers used the procedure in less than 10 per cent of cases. Twenty-nine out of 70 used it in 25 per cent or less of their cases. Those are poor figures indeed compared with the heyday of artificial pneumothorax when the approach to a patient was "try artificial pneumothorax and if it fails..." A more balanced assessment lies somewhere between these two extremes. A careful selection of cases coupled with a ruthless abandonment of the unsatisfactory pneumothorax does result in an appreciable number of safe and anatomically satisfactory collapses.

In this series artificial pneumothorax had been either maintained for a variable period, or unsuccessfully attempted, in 57 cases. This apparently high incidence of artificial pneumothorax in these patients does not indicate

an unusually frequent application of the procedure in this part of the country, but rather only underlines the remarks already made above. In other words, the intake of patients in this series represents a cross-section of the sanatorium's failures. Artificial pneumothorax had been tried, found wanting and had been unhesitatingly abandoned. The reasons for cessation of treatment were the usual ones of, indivisible adhesions, persistence of open cavitation, atelectasis, effusion, tension cavity, etc. In the remaining cases where pneumothorax was not attempted, the main reason for omitting trial was a radiological appearance which suggested that the procedure would be either impossible or dangerous. In the next chapter, the bugbear of a torn parietal pleura is described as a complication of the operation of extra-pleural pneumothorax and in an attempt to assess the extent of the pleural adhesions it is now our practice to try artifical pneumothorax in every case irrespective of radiological appearances. If an unsatisfactory space results the attempt is abandoned forthwith and operation is resorted to, with the operator fully aware that a thin parietal pleura will necessitate a more careful procedure. Even the previous existence of an artificial pneumothorax, maintained over many months, does not guarantee a widely obliterated pleural sac. At the present time some thought is being applied to the possibilities of

producing a preliminary artificial pleurodesis where a widely free space is known to exist.

Artificial pneumoperitoneum and phrenic nerve interruption can be considered together, as the indications for their application are practically identical. Pneumoperitoneum is rarely employed without its action being rendered selective by concurrent diaphragmatic paralysis. Banyai (1946), one of the pioneers of pneumoperitoneum, remains one of its most fervid exponents and in his book, devoted entirely to the subject, describes the many and varied uses to which it may be put. Generally phrenic interruption nowadays, is produced by simple crushing of the nerve with a resultant probable recovery of function after the lapse of 9 - 18 months. Other operations on the nerve, such as avulsion or excision of a segment, are much more rarely practised, since a reversible paralysis of the diaphragm is the object. The combination of phrenic crush and pneumoperitoneum produces its beneficial effect by the elevation of a paralysed diaphragmatic dome to its maximum relaxed height, by the diminution of the respiratory function of the affected lung and by the mild lung compressing effect it achieves in diminishing degree from below upwards. It has its most successful use in the treatment of recent, predominantly exudative phthisis and within such bounds can produce considerable improvement. Cavities in all zones of the lung may be closed with the

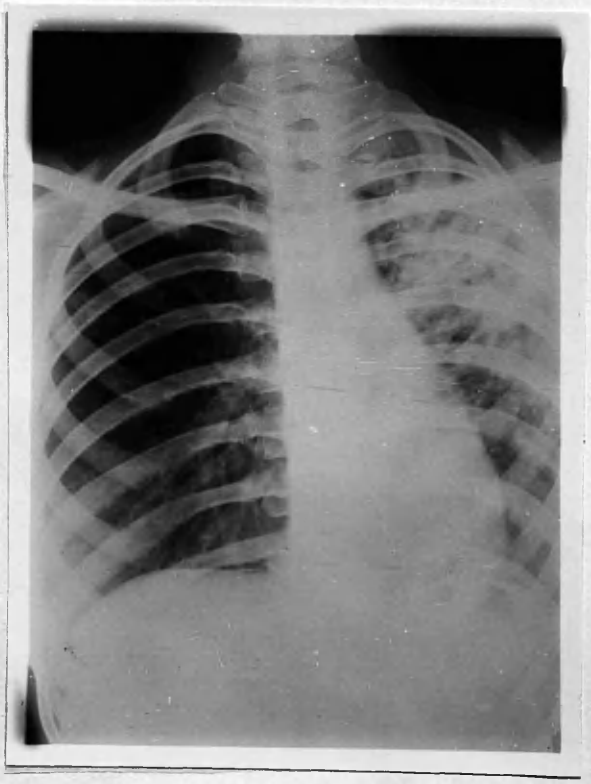


Fig. 3.

proviso that upper and particularly dorsal lobe cavities often prove resistant. It can be a definitive form of treatment in itself and produce complete disease arrest. From the point of view of this paper, the combination of these two measures has its greatest value in controlling basal disease unaffected by extra-pleural pneumothorax prior to operation being performed and also in improving and controlling contra-lateral involvement. Even if absolute success is not achieved with upper lobe excavation, pneumoperitoneum may still produce marked benefit by reducing cavity size and diminishing the extent and activity of the disease. In conjunction with streptomycin and para-aminosalicylic acid its results can be striking. The combination of pneumoperitoneum and antibiotic coupled with bed-rest, indeed comprise the only safe forms of treatment in actively spreading exudative disease. The striking improvement which can be produced by these measures is illustrated in the radiographs reproduced opposite. Fig. 3. shows the x-ray appearances of Case 60 at the time of admission. The patient, a young girl of 16 years, had extensive exudative tuberculous involvement throughout the left lung, with an early unstable deposit in her right lower lobe. After seven months of bed-rest, a four month course of streptomycin and para-aminosalicylic acid, left phrenic crush and pneumoperitoneum, very marked reduction in the extent and activity of the disease had

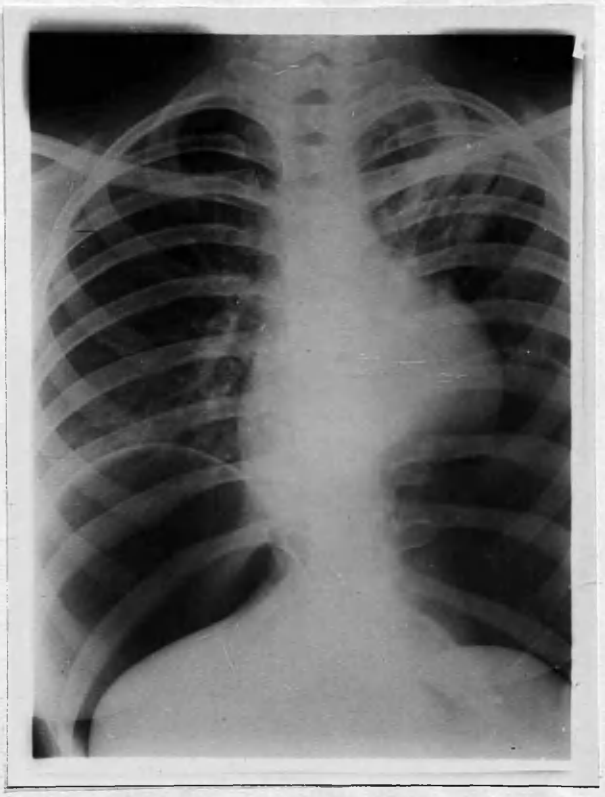


Fig.4.

occurred. Fibrosis of the lesions was commencing and the early right-sided spread had vanished. This gratifying improvement is recorded in Fig. 4 .

Among our cases, phrenic crush operation had been performed, prior to operation, on 29 occasions. In 17 of these it had been amplified by the induction and maintenance of a pneumoperitoneum. The persistence of diaphragmatic paralysis during the actual operation period appeared to have no deleterious effect on the lung, but if operation were performed with co-existent air in the peritoneal cavity boosting the paralysed diaphragm to its optimum height, the risk of total atelectasis of the lung seemed unavoidable. In ten of the 17 cases, pneumoperitoneum had been employed in the preparatory period and had been abandoned several weeks or months prior to operation. In the remaining seven, extra-pleural pneumonolysis was performed with a pneumoperitoneum still present. In three of these patients the diaphragm had recovered its function and the pneumoperitoneum was shallow. No untoward effects resulted. In a fourth case the pneumoperitoneum was being applied to the contralateral lung and again no harm followed. Three patients, however, at the time of operation had a deep selective pneumoperitoneum directed towards the side requiring operative treatment. After operation, all three developed total atelectasis of the lung for a period varying from 10 to 25 days. Complete re-aeration of the lung was

achieved in each instance without any apparent lasting ill effect but in one child the atelectasis was sufficient to reduce the frequency of post-operative refills with a resultant dwindling of the extra-pleural space and ultimate, incomplete disease control. This child later required resection of his lung, which was carried out without incident.

The mechanical reasons for the production of these instances of absorption collapse seem fairly obvious. The lung is sandwiched between two compressing forces. The bronchial calibre is narrowed by the resultant distortion and no doubt, further occlusive help is afforded by tenacious sputum and probably also by minor degress of endobronchial tuberculosis. The atelectasis produced is always rapidly reversible but is none the less undesirable. Thus operation is no longer performed on patients in whom an effective selective pneumoperitoneum is still in progress. The air must either be removed by time or active withdrawal.

C. Medicinal Remedies.

In addition to those minor collapse measures which have just been described, there has also been used in this series a variety of chemotherapeutic and antibiotic aids of very widely divergent values. On the one hand, one patient had received the doubtful benefit of two courses of gold salts in her pre-operative course and one had undergone a short period of treatment with Thioparamizone or T.B.I. - one of

the thiosemicarbazones. At the other end of the therapeutic scale, 43 patients had received courses of streptomycin ranging in duration from seven to 16 weeks. In 39 of these patients, the drug had been accompanied by para-aminosalicylic acid in a daily dosage varying from 12 to 20 grammes and in four the streptomycin had been given alone. A further 38 patients had received para-aminosalicylic acid alone in a daily dosage varying from 15 to 20 grammes.

(a) Gold Salts.

The recipient of the gold salts ultimately came to extra-pleural pneumothorax after a history of tuberculosis extending back over 11 years. Two courses of Myocrisin had been administered in the early forties, when some belief in the efficacy of the drug still lingered. Perusal of her case records and skiagrams of that period show that no material benefit accrued. In the introductory paragraph to the M.R.C. Report on streptomycin in 1948 the value of gold salts in pulmonary tuberculosis is accurately assessed. Referring to the previous lack of controlled trials of remedies for tuberculosis it states - "The history of chemotherapeutic trials in tuberculosis is filled with errors due to empirical evaluation of drugs. (Hart, 1946); the exaggerated claims made for gold treatment, persisting over 15 years, provide a spectacular example." The report goes on to refer to the only controlled trial that appears

to be recorded in the literature and it yielded completely negative therapeutic results. The use of gold in this patient's case is therefore recorded more in the nature of a historic relic.

(b) Thiosemicarbazone.

One patient, also in this series, received a short course of p-acetylaminobenzaldehyde thiosemicarbazone or T.B.I. during the course of her preliminary sanatorium treatment. This drug is one of a number of thiosemicarbazones investigated by Domagk and his colleagues in Germany and found to have a definite inhibiting effect on the Mycobacterium tuberculosis. Much of the original work on this drug was carried out on the Continent and in the British literature, apart from several reports on the pharmacology of the compound, there appear to have been only two papers published so far dealing with its clinical applications. The first by Livingstone and Street (1951) from Lenham Sanatorium, Kent, describes the results achieved with "Thioparamizone" in a small series of 12 cases without clinical controls. The dosage used was on a sliding scale, commencing with 50 milligrammes per day and increasing over a few days to 200 milligrammes, at which level the drug was maintained. The toxic effects, which were relatively mild, included anorexia, nausea, vomiting, lethargy, depression and mild hypochromic anaemia. Four patients

had strongly positive colloidal gold reactions butno overt jaundice. Mild albuminuria was also noted but no evidence of agranulocytosis was forthcoming. They conclude that "Thioparamizone (T.B.I.) has "some value" in the treatment of pulmonary tuberculosis and,as with other similar agents, mainly in the exudative type of lesion. The anti-tuberculous activity they thought, was roughly similar to that of para-aminosalicylic acid and it could probably replace this drug in patients showing intolerance to P.A.S.

The second report emanates also in 1951 from the Research Committee of the British Tuberculosis Association. The main concern of this Committee was more to assess the toxicity of the thiosemicarbazones rather than to estimate their range of clinical application. This cautious attitude resulted from the German reports of an impressive catalogue of toxic effects which ranged from agranulocytosis and haemolytic anaemia to liver and renal damage. As a result the cases used were those in whom streptomycin and para-aminosalicylic acid therapy was not indicated and a chronic fibrocaseous type of disease was chosen. The system of dosage was similar to that of Livingstone and Street. Albuminuria was reported as the commonest side-effect and the other toxic manifestations included, mild hypochromic anaemia, anorexia, vomiting and diarrhoea. No evidence of liver damage was detected. This comparatively minor table of complications was presumably due to the

greatly reduced dosage employed compared with German practice. In the conclusion it is agreed that T.B.I. had some tuberculostatic activity but because of "its increased toxicity as compared to both streptomycin and para-aminosalicylic acid, there must be some doubt as to whether it should be selected at all in planning the treatment of tuberculosis."

"Thioparamizone" was employed in the one patient in this series who received the drug. The dosage was 150 milligrammes per diem and was maintained for eight weeks. At the end of this period, administration was stopped because of a progressive decline in the granular white cells. The girl, who was suffering from extensive caseo-cavernous phthisis, achieved no visible benefit. She was one of a small group of patients, with extensive bilateral fibro-caseous disease, who received the drug at Mearnskirk Hospital in late 1949 and early 1950. No obvious improvement occurred in any of these patients. The conclusion formed at the time was that the continued administration of this drug was undesirable when viewed in the light of the proven beneficial effects of the much less toxic drugs, streptomycin and para-aminosalicylic acid.

(c) Streptomycin.

With the discovery of streptomycin by Waksman and Schatz in 1944, a new era in the drug therapy of pulmonary

tuberculosis was opened. The isolation of the anti-biotic from the Streptomyces griseus was the culmination of a planned search for an agent effective against Gram negative bacteria. Its anti-tuberculous activity was rapidly realised and from 1944-1951 a veritable avalanche of reports has covered every aspect of its origin, pharmacology, toxicity and clinical applicability.

i. Indications for use.

In this country, by means of a well planned series of clinical trials, the Medical Research Council has clarified in excellent fashion the anti-tuberculous efficacy of streptomycin, the lack of effect of intermittent dosage on the emergence of drug fastness in the bacillus and the dramatic reduction of drug resistance brought about by the concomitant use of P.A.S. Their first report, issued in October 1948 demonstrated adequately the drug's efficiency in improving "acute progressive bilateral pulmonary tuberculosis of presumably recent origin, bacteriologically proved, unsuitable for collapse therapy, age group 15 - 25 (later extended to 30)." The dosage used was 2 grammes per day, administered in four 6 hourly injections, and with this dosage, now considered high, the incidence of toxic effects was considerable. The most important one recorded, was damage to the vestibular apparatus. Giddiness was noted in 36 out of 55 patients and lateral nystagmus was a frequent

sign of this vestibular dysfunction. Feldmann and Hinshaw (1948) gave an excellent preliminary review of the results achieved to this date in the various clinical manifestations of tuberculosis. Referring to the pulmonary form of the disease, they also stress the beneficial effect of streptomycin on the relatively acute types of pulmonary involvement. These and many other clinical reports soon afforded adequate evidence that streptomycin in vivo was a very effective tuberculo-suppressive agent. The principle disadvantage in its use was soon obvious however, when every report of its efficacy also contained references to the almost inevitable emergence of resistant strains of the tubercle bacilli after the drug had been used for any appreciable length of time.

ii. Drug Resistance.

When streptomycin is administered alone, the development of bacterial resistance occurs with remarkable facility and rapidity. This unfortunate side-effect is, of course, of very considerable importance in two main ways. In the clinical application of the drug, it cuts short, in varying degree, the time during which a tuberculostatic effect on the organism is possible. In addition it renders unlikely any future benefit to the patient from a second or even third course of the drug. From the public health viewpoint an even more serious disadvantage is the possibility of the widespread dissemination of resistant

organisms with the production of tuberculous disease which is not amenable to streptomycin treatment. This grave danger underlines the necessity of using streptomycin in a logical, planned manner along with other sanatorium measures, so that ultimate disease arrest and sputum conversion is achieved. The gravity of such resistant infection is particularly tragic in the metastatic manifestations of tuberculosis such as tuberculous meningitis where the only hope of a successful outcome lies with streptomycin.

In this series, however, interest centres principally round the first mentioned disadvantage. Streptomycin is in such widespread use as a valuable addition to sanatorium treatment that many patients, before operation is even considered, have required the drug to control, in some cases urgently, the acute progressive form of tuberculosis described above. The revolutionary changes in extra-pleural pneumothorax therapy brought about by the advent of the antibiotic have already been noted and the loss of its protective benefit could be potentially disastrous. No fewer than 43 (43 per cent) of our patients had received streptomycin courses of varying duration prior to operation. Fortunately, as will be seen later, 39 of these patients had received concurrent oral P.A.S. therapy.

In the initial M.R.C. Report (1948), the emergence of drug resistance was noted and the mean date of the appearance

of this, was the 53rd day of treatment. The time of emergence was taken "as that midway between the date of the last sensitive culture and the date of the first resistant culture". Some later accounts have whittled the time lag before the onset of resistance down to a period of between 20 and 30 days. The Research Council Report remarked that "the technique of measuring sensitivity used in the investigation is so slow as to be of little immediate use in estimating, say at the end of one or two months of therapy, whether the course can be usefully continued or not." The principles of the test employed are described by Mitchison (1949) and he recounts three definite grades of insensitivity. In the first group the organisms are about four times less sensitive than H37RV - the standard strain of the tubercle bacillus. The second group are about 126 times less sensitive and the third can grow in at least 1,000 units of streptomycin per millilitre. The measure of the insensitivity of these organisms, obtained during streptomycin treatment, did not alter from one group to another. When a level of resistance had been achieved it was maintained throughout treatment.

The source of the resistant organisms has been a matter for some conjecture but it is now thought that it is perhaps not strictly accurate to say that the bacilli acquire their resistance to streptomycin but rather that there is an innate insusceptibility to the drug already present in a

microscopic number of the bacterial population. These resistant variants become more prominent by multiplication when their more sensitive counterparts dwindle rapidly under the effects of streptomycin. A striking phrase from an annotation in the Lancet (1949) sums up the position. "Streptomycin no more produces drug fastness than a carving-knife produced a breed of Manx mice."

No tests for streptomycin sensitivity were carried out at any stage in our patients for the very practical reason that the time lag of several weeks, which is necessary for definitive results to be reached, would have involved a hopelessly long waiting period for the large number of patients undergoing surgical treatment. With the limited number of beds at our disposal this delay was impossible. In addition, it is surprising that despite obvious x-ray evidence of uncontrolled disease, some patients have difficulty in yielding the tubercle bacillus short of guinea pig innoculation, and thus no organism may be available for assessment. Finally, it was felt that every patient, despite a laboratory report telling of insensitivity, should have the drug even if only on empirical grounds alone. A regular regime of one gramme per day was employed in our cases, as Bignall et al (1950) had already investigated the effect of intermittent dosage of streptomycin on the emergence of bacterial resistance. They used several staggered dosage systems and concluded

that there was no evidence that any of the schemes employed, delayed or avoided the emergence of resistance in the bacilli.

In 1949 a preliminary report issued by the Medical Research Council gave an early statement on the value of P.A.S. in reducing and delaying the development of drug fastness in the tubercle bacillus. A fuller description of the investigation leading to this important finding was published in 1950. Of three groups of patients in this experiment, 59 were treated by P.A.S. alone, 54 with streptomycin alone and 53 with combined streptomycin and P.A.S. The dosage was one gramme of streptomycin and 20 grammes of para-aminosalicylic acid per day. The main conclusions reached were that P.A.S. itself had a definite beneficial influence on acute progressive pulmonary tuberculosis, that the improvement was of lesser degree than that produced by streptomycin and most important of all, para-aminosalicylic acid had "a most marked effect in delaying or preventing the emergence of streptomycin resistant variants of the infecting organisms." Where the bacillus was available for assessment after treatment had been instituted, insensitivity as evidenced by a "resistance ratio" greater than eight occurred in 33 of the 49 cases receiving streptomycin alone, but only five out of 48 undergoing the combined treatment yielded insensitive organisms. In two of those five only a single resistant colony was isolated and later cultures were drug-susceptible. These

findings, confirmed by various authorities, have important, far-reaching implications in the streptomycin treatment of pulmonary tuberculosis. The additional employment of P.A.S. has made possible the much longer effective use of the antibiotic and it has also been made much more likely that repeat courses of the drug will be of full therapeutic value. Thus in large numbers of cases streptomycin may be used, both to bring the initial ravages of the disease under control and later to provide effective drug cover for operative treatment. This fact has been utilized to the full in the patients in this series. It will be noted already that only four of our cases had received streptomycin alone. The remainder had had the additional benefit of P.A.S.

Illustrative Case Report:

The value of combined streptomycin and P.A.S. preparation for operation is very strikingly displayed by study of one of the case reports from this series.
Case No.58. D.G. - a male youth of 18 years was admitted to a sanatorium ward of Mearnskirk Hospital early in 1950, four months after the diagnosis of his tuberculous infection. He was in fair general condition but somewhat toxic. His chest skiagram showed extensive massive tuberculous involvement of the entire right lung. In addition there was an area of recent tuberculous infiltration in the second left interspace. There were numerous moist adventitae

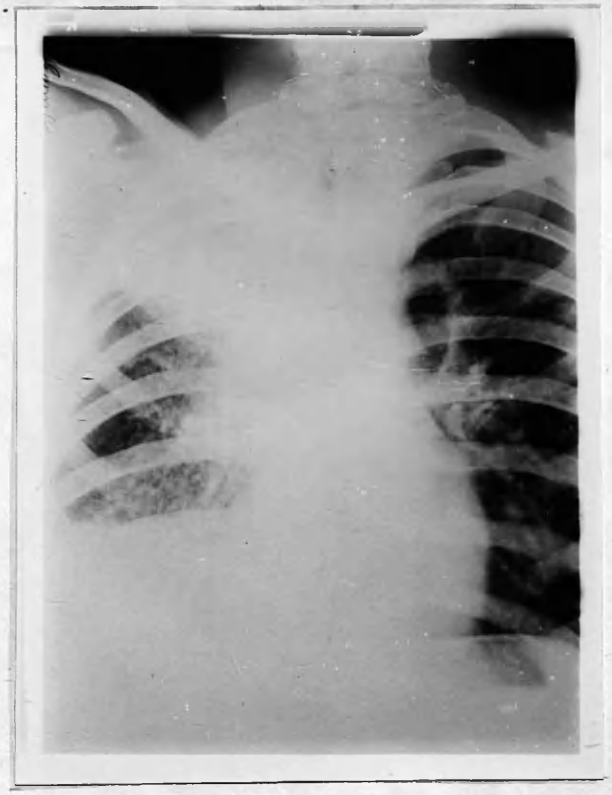


Fig.5.

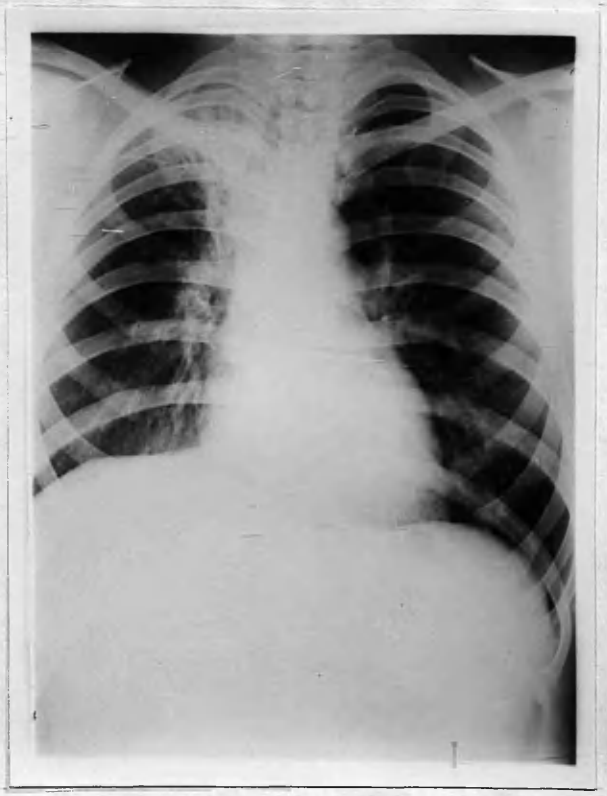


Fig.6.

throughout the right lung and the sputum was strongly positive for tubercle bacilli by direct smear. His B.S.R. was 50 millimetres in the first hour (West.). A regime of bed-rest, and combined streptomycin and P.A.S. therapy was commenced immediately. The dosage adopted was one gramme and 12 grammes per diem respectively of these drugs. The streptomycin was maintained for four months and thereafter the P.A.S. was continued alone in the dosage of 18 grammes per diem. A dramatic improvement in general condition resulted and the radiological changes are depicted in Figs. 5 and 6. These photographic plates represent his skiagram at the time of admission and the appearances immediately prior to operation. The disease in the latter, has receded spectacularly and the residue is represented by a fibrotic, contracted right upper lobe which contained several minor cavities. The lesion in his left lung had become more discrete. His B.S.R. was 2 millimetres in the first hour (West.), and tubercle bacilli had disappeared from direct smears of his sputum.

iii. Toxicity.

The sustained administration of streptomycin in the treatment of tuberculous infections is liable to produce in some patients various symptoms of drug intolerance. Some of the earlier toxic manifestations described in the literature could probably be attributed to the impurities in the streptomycin preparation then in use. The frequency of

their occurrence has fallen off considerably in latter years and reflects the gradual progression from the early impure hydrochloride and sulphate salts via the calcium chloride complex to the dihydro-preparations which are in use today. Withdrawal of the drug promotes gratifying if slow improvement in all these side effects and the appearance of any of them is the signal to abandon treatment entirely. The toxic symptoms which have been recorded in the literature include nausea, vomiting, headache, vertigo, multiform skin rashes, ulcerative stomatitis and pharyngitis, etc. With the comparatively small dosage now employed in pulmonary disease, we have found with dihydrostreptomycin an almost complete abolition of the gastro-intestinal symptoms, headache, and skin rashes. The previously high incidence of vestibular nerve damage caused by the earlier salts has also been reduced dramatically. (Giddiness occurred in 36 out of 55 patients in the M.R.C. Report, 1948). Upset of vestibular function is evidenced by giddiness, lateral nystagmus, positive Romberg sign, ataxy of gait, etc. Persistence with the drug ultimately produces complete destruction of the vestibular apparatus. Indeed this unfortunate property of streptomycin has been employed therapeutically in Ménières disease. Cessation of treatment causes gradual improvement in the symptoms, which may completely resolve.

The neurotoxic quality of streptomycin provided the main incentive in the search for an equally effective and less poisonous agent. The production of dihydrostreptomycin was the outcome of these activities and there is now a growing body of evidence which indicates that this drug is much less likely to produce, toxic side-effects in general and symptoms of nerve damage in particular. Dihydrostreptomycin is prepared synthetically by the catalytic reduction of streptomycin and is a base capable of producing salts.

Edison et al (1948) describe an experimental assessment of the new compound in cats, dogs and monkeys. They conclude that dihydrostreptomycin and its parent substance are closely comparable in anti-bacterial activity against the tubercle bacillus, that organisms resistant to the one are also resistant to the other and that the chronic neurotoxicity of dihydrostreptomycin, at least in cats, is less than that of streptomycin. Feldman et al (1948) reached similar conclusions as to the anti-tuberculous activity but made no comment on nerve damage potential. A diminished incidence of vestibular upset, however, was reported by Hobson and his colleagues (1948) and they also commented on the fact that patients who are hypersensitive to streptomycin tolerate the dihydro compound well. This latter fact has been confirmed in one patient in this series. After six weeks administration of one gramme of streptomycin sulphate daily,

the patient, a woman of 30 years, developed giddiness and nystagmus. The drug was abandoned. Several months later she was re-admitted with an exacerbation of her disease and had subsequently two three-month courses of dihydro-streptomycin, one to bring her disease under control and one to cover her extra-pleural pneumothorax. She showed no evidence of neurotoxicity whatsoever. Further confirmatory evidence of the efficiency and diminished toxicity of dihydrostreptomycin is supplied by Hinshaw and his co-workers (1948).

As a result of these investigations dihydrostreptomycin sulphate has completely supplanted the older streptomycin salts at Mearnskirk Hospital during the past two years, both in the routine treatment of pulmonary tuberculosis in the sanatorium wards and also in the operative cover of patients undergoing surgical treatment for their disease. The results have been gratifying. Toxicity in general and neurotoxicity in particular have been considerably reduced. In the present hundred cases, only two patients have shown evidence of neurotoxicity during the immediate post-operative period and on both occasions the drug was stopped without ill effect on the course of the pneumothorax. Both these patients had previously received courses of the anti-biotic in other hospitals. As many of our patients were transferred to their original hospitals in the second or third post-operative week, no accurate details are available

for the complete post-operative course of the drug. Sixty-two of them however completed their courses at Mearnskirk without any untoward incident.

(d) Para-aminosalicylic Acid.

i. General Remarks.

In 1946, Lehmann, amid much less publicity quietly described the events which led to the discovery of para-aminosalicylic acid (P.A.S.). Bernheim had initiated investigations several years previously when he observed that salicylic and benzoic acids increased the oxygen intake of the tubercle bacillus. Lehmann and his colleagues sifted 50 derivatives of benzoic acid before P.A.S. was discovered to be the most tuberculostatic compound. He reported beneficial effects with the drug in limited clinical trials.

Since Lehmann reported the results of his work in Sweden a flood of reports, similar in dimensions to those on streptomycin, has described the pharmacology, toxicity and uses of this compound. With the prominence of drug resistant strains of the tubercle bacillus so important a factor in streptomycin therapy, it is interesting to observe that Lehmann (1947), Bavin (1949), Nagley (1949), Graessle et al (1949) all report that resistance to the drug is conspicuous by its absence. Goodacre and Seymour (1949) found a resistant culture on only one occasion in 25

patients undergoing treatment. A higher incidence of resistance, however, is recorded in the 1950 M.R.C. findings, where it is noted that no fewer than eight patients out of 24 having gross cavitation, developed insensitive strains. In 13 other cases without such marked excavation, no resistant cultures were obtained. These authorities also comment on the fact that the test they employed for assessing sensitivity was unreliable. Despite the uncertainty of this test, it does appear that some strains of the tubercle bacillus insensitive to P.A.S. do emerge during treatment, on more occasions than the earlier, optimistic reports would suggest. Further investigation of this aspect of therapy with a more reliable laboratory test should clear up the question.

Dempsey et al (1947) and Madigan et al (1950) have described the direct antibacterial effect of P.A.S. on the bacillus. Besides reduction of the bacillary population, they describe morphological changes, including striation and beading in the bacilli. Ivanovics (1949) and Hurni (1949) have described respectively the P.A.S. antagonising effect of salicylic acid and p-aminobenzoic acid. Coming nearer home, Wilhelmi (1950) after discussing the treatment of tuberculous empyema in some detail, states that extra-pleural empyemata respond better to local treatment with P.A.S. than do intrapleural infections. Horne and Wilson (1949) have investigated the action of caronamide in patients

receiving P.A.S. By inhibiting tubular excretion of the drug in this way, higher blood levels can be achieved and they are investigating the therapeutic significance of these findings.

ii. Toxic Effects.

The toxic effects of P.A.S. include, nausea, vomiting, diarrhoea, lethargy, skin rashes (especially urticarial) and occasionally acute evidence of drug sensitisation. The first four of these are relatively common but never dramatic and are readily removed by cessation of treatment. Urticaria may be severe but usually responds rapidly to the usual measures, adrenaline, antihistamines and withdrawal of the drug. Drug sensitisation is rare but none the less spectacular. It is characterised by a sharp, short pyrexial illness with generalised aches, malaise, anorexia and misery. The temperature may reach 104° Fahrenheit. The symptoms disappear as rapidly as they come. Such an occurrence forbids further P.A.S. administration unless desensitisation is carried out. (Climie, 1950). In these sensitised patients he discovered marked skin reactions to patch tests using 20 per cent P.A.S. and solutions of m-aminophenol ranging from 1 per cent to 20 per cent. He considers that a derivative of m-aminophenol is the sensitising agent in severe skin reactions.

iii. Clinical Applications.

In therapeutic application, P.A.S. runs an almost

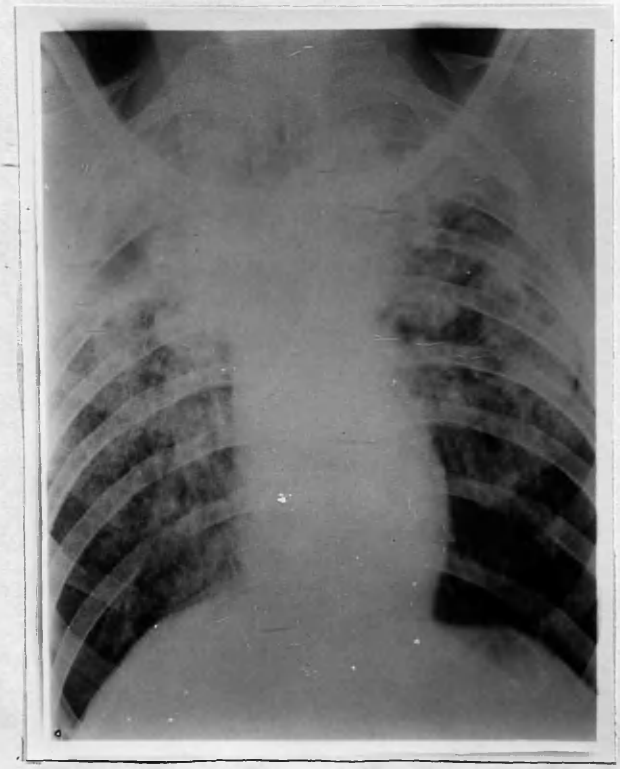


Fig.7.

parallel course with streptomycin. It procures its most successful results in the recent exudative lesion. In our cases it has been used in a manner similar to streptomycin, viz. to control the initial ravages of progressive disease, and, when a more productive phase has been reached, to implement the operative cover affected by the antibiotic. Thirty-eight of our patients received the drug in this way and the illustrative case report set out below demonstrates what can be achieved by the combined pre-operative preparation of P.A.S. and bed-rest.

Case No.76. - A male patient of 32 years had suffered from bilateral phthisis for 11 years. At the commencement of his illness he had undergone a short period of sanatorium treatment and a right artificial pneumothorax had been induced at this time. The collapse was maintained for a period of three years but was never totally effective because of apical adhesions. During the eight years prior to admission in 1950 his story had been one of fair general health between irregular but fairly frequent exacerbations of his disease. With each relapse, the disease gained more ground until finally, on admission in March 1950, his x-ray reproduced opposite, showed bilateral fibro-caseo-cavernous disease of both upper halves, with widespread dissemination of more exudative tuberculosis in the remainder of his lung fields.

His sputum contained tubercle bacilli and his B.S.R.

was 98 millimetres in the first hour (West.). He was treated by bed-rest and P.A.S. in the dosage of 18 grammes per day and 10 months later his radiological appearances were those recorded in Fig. 8 . At this time, though realised to be not an ideal case for operation on account of the widespread permanent structural changes in his lungs, he was accepted for bilateral extra-pleural pneumothorax treatment as no other procedure was feasible. His right side was operated on in February 1951 and one month later his left extra-pleural pneumothorax was established. Fig. 9. shows his position in October 1951, by which time he was attending as an out-patient for refills of both spaces. His sputum was repeatedly negative and his B.S.R. was 8 millimetres in the first hour (West.).

2. OPERATIVE TECHNIQUE.

A. Drug Cover for Operation.

In every patient in this series, the operation itself and its immediate post-operative course have been covered by the routine use of streptomycin, penicillin and para-aminosalicylic acid. Dihydrostreptomycin sulphate in the dosage of one gramme per day is commenced a week before operation and is accompanied in the usual manner by 12 grammes of P.A.S. daily. P.A.S. is not utilised over the first 10 post-operative days on account of its tendency to

produce nausea and its place is taken during this time by penicillin which is administered in half million unit doses, twice daily. Thereafter P.A.S. resumes with the streptomycin and continues with it until the completion of a 90 gramme course of the antibiotic. When the streptomycin administration is completed, P.A.S. may be continued alone in an increased dosage of 18 grammes daily, dependent on the condition of the patient. In most cases it is continued until the time of dismissal from sanatorium. The topical use of streptomycin and penicillin is described later in the section on post-operative management.

The value of streptomycin as cover for thoracic operative procedures in the tuberculous patient has been described by various authorities but almost entirely in connection with thoracoplasty and resection of the tuberculous lung. Mulvihill et al (1949), Chapman et al (1949), Moore et al (1949) and Samson (1948) all testify to its efficacy. But in the sphere of extra-pleural pneumothorax, Cutler (1951) is almost alone in describing the remarkable changes brought about by these recent drugs in this form of treatment. Referring to streptomycin, penicillin and P.A.S. he says "Those drugs have literally saved this operation." His series of 129 operations in 121 cases includes over 60 operations covered by modern drug therapy. The considerably improved results from 1945 onwards he attributes in great part to streptomycin. His

results are strikingly confirmed by the findings in this series. The opinion in this centre is that the cover afforded by the modern antibiotics has converted extra-pleural pneumothorax from a dangerous and potentially lethal procedure to one that is safe and relatively free from distressing complications.

B. Abbreviated Description of Operation.

The treatment of pulmonary tuberculosis by very reason of the chronicity of the process, frequently covers an extensive period of time and it is with the evolution of extra-pleural pneumothorax as an incident, albeit a fairly dramatic surgical incident, in this history of the disease, that this survey is primarily concerned. The operation therefore must be considered against a background of the various ancillary sanatorium measures by which it is both preceded and followed. The details of operative procedure are thus mainly the basic ones and no attempt has been made to provide a full surgical conception of the operation.

The operation carried out on the patients in this series is very similar in detail to that already described by many authorities in the past. In chronological order, a selection of them includes, Mayer (1913), Nissen (1931), Graf (1935), Brock (1938), Sellors (1938), Proctor (1940), Reid (1946), Murstad (1951), etc. etc. Most of them employ an oblique

or vertical paravertebral incision but an anterior approach through the first or second interspace is described by both Davies (1924) and Romanis and Sellors (1935). Pierre-Bourgeois and Lebel (1938) and Garraud (1948) describe an axillary attack. The advantages of the latter, they allege, are an easier pneumonolysis, a better closure and a hidden scar.

The paravertebral route was adopted here as being most likely to afford the best access to the most adherent part of the lung in the paravertebral gutter. Experience, in something approaching 200 cases at the time of writing, has confirmed this line of reasoning. With the patient in the semi-lateral position and the arm on the affected side drawn forward, thus rotating the scapula in its long axis, the incision is a straight oblique one some five to six inches long and running upwards and inwards from the inferior angle of the scapula towards the spine. Ready entry is achieved in this way to the triangle of auscultation through which access is gained to the ribs. The trapezius muscle is exposed. The layers of its investing fascia join along its lower border and pass downwards in a sheet to split and cover in turn the latissimus dorsi. This layer is incised along the lower border of the trapezius and the fascial covering of the rhomboids then comes into view. It in turn is split, the rhomboids are retracted upwards and thereafter easy access to the ribs is attained.

This muscle conservation incision preserves admirably the full function of the shoulder girdle and in this series has been perfected by a process of evolution. Originally a curved circumscapular incision was employed. Then followed an oblique paravertebral incision and after it a vertical one. With each of these approaches the trapezius was cut and the rhomboids split. There was, however, a natural disinclination to cut muscle tissue with possible later loss of function and in keeping with the general aesthetic qualities of the operation, the muscle conservation approach described above was perfected. No mention of such a conservative exposure in extra-pleural pneumothorax surgery is made in the literature on the subject.

By this route the posterior portions of the ribs are adequately exposed and resection of a four or five inch portion of the fourth or fifth rib is carried out. Through the rib bed access to the extra-pleural plane is readily achieved by a process of blunt dissection with the finger and the separation of the lung is commenced. The finger-stripping procedure is continued in this plane with the additional assistance of small gauze swabs mounted in sponge holding forceps to continue the mobilisation in inaccessible areas. A malleable lamp carrier provides illumination in the darker recesses of the space. A variable amount of oozing occurs but regular application of gauze packs immersed in warm saline, suffice to control this in most

instances. Major hæmorrhage at operation has not been encountered in this series. The strip is continued until the apex of the lung is fully mobilised with the azygos vein exposed on the right side and the arch of the aorta on the left. The inferior limits of the space usually extend to the seventh or eighth ribs posteriorly and this level is carried circumferentially round the chest until the third costal cartilage is bared in front. Careful attention is paid to the anterior limits of the strip to ensure that the first and second interspaces are adequately cleared. This contributes to ease in refilling the space, particularly when later maintenance is carried out at chest clinics where the second intercostal space anteriorly appears to be the site of election for needling. This is done sometimes irrespective of the fact that the lung margin may cross those spaces and must thus be traversed before the needle tip enters the cavity. The resultant frequent trauma of the lung could potentially provide a late cause for empyema.

The separation of the lung is carried out slowly, taking care to direct the pressure, from the gauze pad held by the forceps, against the chest wall more than the receding lung. In this way, the risk of damage to lung parenchyma is very much lessened and the possibility of tearing the parietal pleura reduced. If the strip becomes difficult in any one part this area is temporarily abandoned and another

section commenced. Eventually by a process of patient encirclement even the most tenacious areas can be separated. The dangers of inflicting damage on the lung substance and of tearing the parietal pleura are more fittingly described under the heading of complications. It may however be mentioned that in the 105 operations under review there was only one instance of damage to the lung. This was of a very minor nature and consisted of a small area of lung the size of a postage stamp denuded of its visceral pleura, with a very superficial peeling of some of the surface alveoli. Inflation of the lung by the anaesthetist under some pressure produced a few bubbles of air. The operation was continued and the space has now been maintained by air refills uneventfully for more than 15 months.

In some patients the parietal pleura is discovered at the time of operation to have the thickness of very fine tissue paper. The intrapleural space is widely free and the underlying lung glides back and forth with each phase of respiration. Quite frequently the only area of symphyisis between the pleural layers is over a small apico-posterior zone in the paravertebral gutter. This limited area of adhesion is quite sufficient to render an intra-pleural pneumothorax useless and the otherwise widely free intra-pleural space makes an extra-pleural mobilisation of

the lung a matter fraught with considerable difficulty. The parietal sheet tears on the slightest provocation and extreme care must be exercised if a combined space is to be avoided. There has been no deliberate attempt in this series to perform what is referred to as the 'combined' operation. In this variety of extra-pleural pneumothorax, after the apex is mobilised in the usual manner, the bridge of parietal pleura below is divided widely and a combined intra-extra-pleural space formed. It was felt that with this procedure the selective effect of the 'standard' extra-pleural operation was immediately lost and it had been noted that the earlier reports e.g. Roberts (1948) had listed a much higher incidence of later complications, particularly tuberculous empyema in those cases. On one occasion an extremely thin parietal sheet was accidentaly torn widely just as the extra-pleural plane was being ascertained. As no repair was possible the tear was extended circumferentially in both directions round to the mediastinum and after extra-pleural mobilisation of the apex an extensive combined space was made. This, our solitary experience with an accidental combined operation, has had a successful outcome, the space being maintained satisfactorily for over a year now.

When effective apicolysis has been carried out, haemostasis is readily achieved by packing the space with several large gauze swabs, previously immersed in warm saline. The usual bleeding encountered, mostly occurs in the form of

a generalized oozing from the raw surfaces of the walls of the space. Nissen (1931) uses gauze soaked in 40 per cent alcohol as a haemostatic. Mullard (1948) describes the use of calcium alginate as a means of controlling haemorrhage. He paints the walls of the space with a gauze sponge soaked in sterile four per cent sodium alginate solution. Two per cent calcium chloride solution is then applied and conversion to a film of calcium alginate takes place. He reports 11 consecutive cases without haemorrhage. Alginate was used on two or three occasions in our cases but did not impress either in ease of application or haemostatic activity. The only vessel which has been deliberately ligated and divided on several occasions has been the lateral costal branch of the internal mammary artery. This artery, coursing as it does, obliquely outwards and downwards from its origin in the internal mammary artery is suggested by Cleland (1948) and Kropp (1951) as a possible cause of haemorrhage in extra-pleural pneumothorax when refills and aspirations are carried out via the first or second intercostal space anteriorly. The arterial branch with its two venae comites, runs obliquely downwards across the first, second and third interspaces. Cleland noted its presence in 42 out of 70 thoracoscopies and at five out of 12 extra-pleural operations. Kropp investigating the artery at 112 post-mortems recorded its presence on one or both sides in 31 (27.6 per cent).

In 10 it was present only on the right side, in 15 it occurred on the left and in six instances the artery was present on both sides. Because of Cleland's report the artery when seen in our early cases was frequently ligated. Some doubt as to the likelihood of impaling the artery at refills, however, led later to an abandonment of this routine search. As no haemorrhage has resulted in what must now amount to many hundreds of aspirations and refills of these cases by the anterior route, no attempts at routine ligation are now made. When all progressive haemorrhage is arrested, the space is about three-quarters filled with tepid normal saline with the topical addition of 100,000 units of penicillin and one gramme of dihydrostreptomycin sulphate. The gap in the intercostal bundle is repaired by interrupted catgut ligatures and as no muslce planes have been incised, comprehensive interrupted nylon sutures, taking in the deep fascia, suffice for the skin. Authors, too numerous to mention, stress the necessity of an air-tight closure. This, to us, appears an impossible fallacy with a fresh wound and stress should rather be placed on rendering the wound completely watertight. Some subcutaneous emphysema, although usually slight, is inevitable. No drainage tube is used. Graf (1936) advocates the use of a gum elastic catheter to reduce emphysema and Murstad (1951) recommends routine drainage as a means of reducing the frequency of post-operative aspirations.

The employment of saline as a space filling agent has just been mentioned. The thought behind its use originally was the fond hope that it might prevent premature re-expansion of an over buoyant lung and thus render the early aspirations and refills easier to execute. These hopes were quickly dispelled when portable post-operative films taken a few hours after operation showed the almost total absorption of amounts up to a pint. Various other space filling agents have been investigated from time to time in the search for an innocuous substance, which would simultaneously maintain the lung collapse for several days by passive persistence in the space, and also minimise the incidence of massive clotting of the effused blood. Sodium citrate solution in the strength of 3.8 per cent was used in two patients to assess its anti-coagulant properties. Murstad (1951) uses 300 cubic centimetres of one per cent sodium citrate with the same object in view and renews this solution frequently in the first four post-operative days. He reports that it does not altogether prevent clotting but is a "considerable help." The citrate idea was rapidly given up when one of the recipients had a massive reactionary extra-pleural haemorrhage necessitating urgent aspiration and replacement transfusion. Plasma was next thought of, as a more persistent solution with which to fill the space. In varying amounts it was employed in 18 cases and, if anything, did appear to remain somewhat longer. Its use was also

abandoned when retrospective consideration of its qualities suggested an increased tendency to massive clotting in the extra-pleural space. In addition, the fear of homologous serum jaundice, though not confirmed later, was a further deterrent. At the present time, one of the proprietary plasma substitutes is being investigated as a candidate for the ideal temporary space occupying substance.

C. Anaesthesia for Extra-Pleural Pneumothorax.

General anaesthesia has been employed in all our patients. Induction is achieved with 0.4 to 0.5 gramme of intra-venous pentothal, adequate relaxation is procured by curare or one of its newer synthetic derivatives and maintenance is provided by closed-circuit cyclopropane delivered via an endotracheal tube. The advent of these modern, smooth, anaesthetic techniques with their minimum of post-operative upset, has made the local anaesthetic methods described by many of the earlier workers, unnecessary. They were, the writer believes, used largely because of the absence at that time of a safe, non-irritating anaesthetic procedure for a patient with pulmonary tuberculosis. The great majority of the reports in the last ten years describe the use of general anaesthetic agents and frequently mention cyclopropane. The absence of any instances of post-operative spread of disease in 105 operations underlines the safety of these methods.

D. Defective Mediastinal Separation.

In our earlier patients the standard apicolysis described above was not always achieved, particularly with reference to the mediastinal strip of the lung which on several occasions was inadequate,and in one or two cases was not even commenced. A contra-mediastinal collapse resulted and in several patients procured satisfactory disease control. The defective mobilisation is readily acknowledged by the surgical team as being due to early inexperience with the operation. It occurred three or four times in the first 20 operations and since then a complete mediastinal separation has been achieved in every case. Most contributors to the literature agree that this clearance of the mediastinal aspect is a desirable thing but Cutler (1951) and Head and Moen (1948) stand out alone in advocating that the lung be left adherent over this part of its surface. They argue that if the lung is fully mobilised on all its aspects there is a danger that apical cavities, particularly if of appreciable size, may be displaced bodily downwards without being effectively closed. To continue with pressure refills in such circumstances is useless. By leaving the lung adherent to the upper mediastinum the cavity can be effectively compressed in a medial direction, as Cutler descriptively remarks "the mediastinum acting as a sort of anvil and the pneumothorax

refills as the hammer." The ineffectual downward displacement of cavities when the mediastinal surface of the lung is freed has not been observed in our cases and where an adequate space is produced, cavity closure followed inevitably. To implement this contra-mediastinal collapse, Cutler also advocated more extensive stripping of the lung in its lower parts. Where extensive disease is present he mentions the eighth or ninth rib posteriorly and the fourth costal cartilage anteriorly as the lower extremities of the space. Despite the admirable results which he has achieved with this method, it is felt that the very extensive extra-pleural pocket which is produced, at once vitiates one of the operations most frequently lauded advantages - the selective nature of the collapse.

E. Failure to Establish a Space.

Complete failure to establish an effective extra-pleural space has not occurred either in the cases under consideration or in any of the subsequent operations performed between April 1951 and the date of writing this survey. Several of the earlier writers report complete inability to mobilise the lung in varying numbers of cases. Brock (1938) for example, records that the operation was impossible in no fewer than six of 50 cases and Murstad (1951) could not commence separation in 21 (3 per cent) of his patients. This relatively high incidence may have been due to the choice of

a much more fibrotic chronic type of lesion. The table set out below records the type of operation performed in the patients being described.

TABLE NO.3.

PROCEDURE	NUMBER
Abandoned on table	0
'Standard' operation	104
'Combined' operation	1
Total number of operations in 100 patients.	105

3. POST-OPERATIVE MANAGEMENT.

A. General Remarks.

The majority of patients coming to extra-pleural surgery have undergone beforehand a variable period of sanatorium treatment. The disease process has been stabilised, the toxicity reduced and the general condition frequently very markedly improved. The capacity of the patient to withstand this surgical intervention is correspondingly very good and in the great majority of our patients the post-operative upset was slight. Indeed it compared favourably with the aftermath of the average thoracoplasty stage. A certain amount of diffuse upper chest pain is the rule but shock is conspicuously absent. The discomfort is readily alleviated by small doses of

omnopon repeated at intervals of four to six hours as required. Initially the custom was to use morphine in the dosage of a quarter of a grain but when moderate post-operative haemorrhage occurred with or without clotting of the blood, the addition of this amount of morphine to the respiratory disability produced by the effusion, gravely aggravated the symptoms. The additive effect of morphine on the respiratory embarrassment caused by haemorrhage into the space, almost produced a fatal outcome in one patient. Aspiration of some of the space contents saved him. In the dosage of one sixth of a grain, omnopon can readily be repeated if the desired pain relieving effect is not obtained. No respiratory depression results from such minor amounts.

It was the custom also in our early cases to discourage post-operative coughing, both by exhortation and by a number of sedative cough linctures. The object was to minimise the expulsion of air through the wound with resultant reduction of space and discomfort from subcutaneous emphysema. The limitations of the abolition or reduction of the cough reflex were soon apparent. The overwhelming majority of patients undergoing thoracic surgery have an increased secretion of sputum in the post-operative period and when the operation has the collapse of the tuberculous lung as its object, the amount of sputum may be very considerably increased indeed. In every such operation the expulsion

of this sputum is encouraged by every known means. Some of our early cases were discouraged from coughing by means of anti-tussives and well intended advice on the grounds that premature re-expansion of the lung and extensive emphysema might result when the air contents of the space were expelled by the effort. The patient obeying these instructions was subjected to an almost continual stimulation of his cough reflex produced by sputum in his bronchial tree. By volition he smothered his cough and the abortive effort merely moved the sputum to another bronchial site where it remained until further reflex simulation pushed it a few more centimetres. Eventually, when suppression was no longer possible, the sputum was more or less blurted out. This continual niggling cough produced endless discomfort and probably more expulsion of space air than a series of widely spaced productive efforts. We thus no longer try to suppress coughing but rather encourage periodic productive attempts covered by omnopon grain 1/6 to minmize pain. In this way effective clearing of secretion is obtained and exhaustion obviated. After the first few days expulsion of sputum ceases to be a problem. Indeed the rapid reduction and sometimes complete disappearance of sputum is a frequent feature of the early post-operative days. Patients with copious sputum before operation often spontaneously remark on this. The initial early increase, which results from acute compression of the diseased and excavated lung,

rapidly dwindles and with full establishment of the space, disappears.

For the same space-conservation reasons, physiotherapy does not play an important part in the post-operative management. Grigor (1951) has outlined the valuable role of the physiotherapist in the pre and post-operative control of the patient undergoing thoracoplasty. By comparison in extra-pleural pneumothorax treatment, their activities are confined to the assessment of the vital capacity before and after operation and to the maintenance, in the first few post-operative days, by means of passive and assisted movement, of the mobility of the affected shoulder joint. The thoracic cage in extra-pleural operations of course remains intact and posture is, without exception, excellent. In contrast to thoracoplasty also, these patients, if general condition permits, can be allowed to toilet at the end of two to three weeks. This early mobilisation further diminishes the risk of bad post-operative posture which can result from prolonged slouching in bed.

In some of the American descriptions of the operation, a very impressive account of routine post-operative measures is given. They range from routine saline transfusions, via half hourly pulse and blood pressure readings, to retention enemata of black coffee. These anti-shock measures have not been required in this series. A replacement blood transfusion to a maximum of two pints has been required in

three out of 105 operations. In two of these patients exsanguination was not marked and the one pint transfusion given was probably unnecessary.

B. Aspiration and Refills.

Extra-pleural pneumothorax occupies a somewhat unique position among thoracic surgical procedures, in that although the actual operation may be performed with meticulous attention to detail, a successful outcome is dependent almost entirely on skilful, industrious, post-operative aspiration and refill. Alley (1946) states, "We feel that the refills and management of the extra-pleural space, especially during the first two weeks, determines the success or failure of the procedure." Despite these remarks, perusal of a cross section of the literature soon makes it obvious that each operator holds his own definite views on how this period should be planned. The apparently simple question of the opportune time for the first air refill of the space causes quite considerable divergence of opinion. The majority view appears to be - "the sooner the better". Brock (1938), Dolley et al (1940), Newton et al (1940), Alley (1946), Reid (1946) and Friedman and his colleagues (1949) are among those who advocate a space refill either at the end of operation or on return to the ward. On the other hand Mullard (1948) leaves his patients until the fourth post-operative day and Proctor (1940) extends this period

to five or even seven days. Because of this the description set out below gives an account of the method evolved at Mearnskirk Hospital during the past two years. It embodies many of the points made by the authors mentioned above and appears in our hands to be the most satisfactory method.

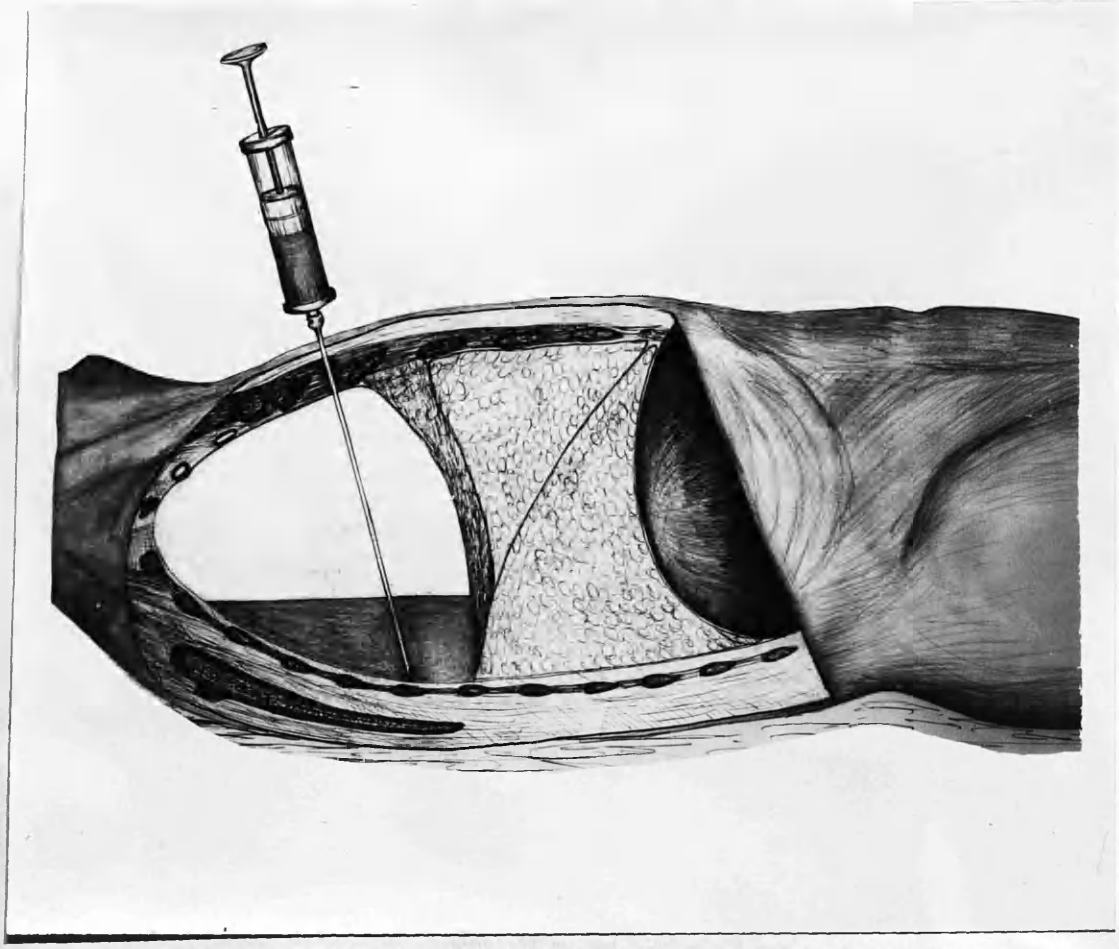
The space is not refilled at the termination of operation as the lung, at this stage, seems fairly adequately buffered from the chest wall by one or other of the space-filling agents referred to previously. These agents though, in general, rapidly absorbed during the first 12 to 18 hours, suffice to prevent premature re-adhesion of the lung to the thoracic cage. A skiagram of the chest by portable apparatus is taken on the first post-operative day. At this examination the question of early refill of the space can be decided. By and large the patients requiring a refill at this time can be fairly accurately predicted at the time of operation. A buoyant elastic lung which does not fall away from the chest wall after mobilisation indicates, almost unfailingly, the necessity for refill within the first 24 hours. This buoyant quality, of course, usually accompanies fairly limited upper lobe disease and has not been noted very frequently in our patients. The majority of our cases had more extensive, fibrotic disease and the lung under these conditions, particularly when weighted down by the addition of a moderate collection of

blood in the space, was not prone to premature re-expansion. Even at routine fluoroscopy on the second day, these lungs showed little tendency to expand and the main reason for interfering at this stage was to remove the almost inevitable sanguineous effusion before clotting or deposition of fibrin occurred.

A minority, therefore, of our patients required space refills after 24 hours and in most instances aspiration and refill was delayed until the second day or even, in some cases, to the third day. In this operation, leaving as it does, a 'dead' space, a certain amount of post-operative haemorrhage is inevitable. The quantity of blood effused is usually small and readily dealt with by careful aspiration.

C. Techniques.

Scrupulous attention to asepsis is, of course, essential. Aspiration is performed in theatre with the patient in the supine position. The site chosen for entry is the first intercostal space in the mid-clavicular line. After careful infiltration of the chest wall with six to eight cubic centimetres of two per cent Novocain, a medium calibre aspirating needle, some six to seven inches in length, is slowly introduced into the space almost vertically downwards, its onward path being guided by tactile sensations conveyed through the hilt. A characteristic sensation of 'give' marks the entry of the point into the space and thereafter



Diag. 1.

The diagram reproduced above illustrates the position and technique of aspiration. The needle inserted through the first intercostal space is dredging the paravertebral pool. The lung has not been stripped from the second interspace. This defective anterior separation is referred to later.

the needle can be glided slowly further in until its tip impinges on the posterior space wall in the paravertebral gutter. This manoeuvre can be accomplished in perfect safety if attention is given to the complete lack of resistance felt in the guiding fingers as the needle moves slowly inward. Dolley et al (1940) list the four criteria of space entry as:- (a) the typical give on entering the space (b) the lack of resistance to onward progress (c) the aspiration of fluid or air and (d) the characteristic manometer pressure which they quote as swinging between -4 and +4 centimetres of water. With practice the latter two of these standards become unnecessary.

With the patient in the supine position the effused blood collects in the paravertebral gutter. For efficient dredging of the pool the needle must be capable of reaching the posterior wall of the space in the bottom of the gutter. A length of six to seven inches has been mentioned and particularly in well developed male patients is required to the last millimetre. Removal of the effusion is carried out by a 20 cubic centimetre syringe, without the assistance of a two-way tap. In order to maintain the space during aspiration an equivalent amount of air is introduced as each syringe-ful of blood is removed. When the space is dried, as far as possible, 1,000,000 units of crystalline penicillin in 10 cubic centimetres of sterile water and one gramme of streptomycin in solution are inserted. The needle

is then connected to a pneumothorax refill apparatus of the Maxwell type and the pressures measured. They are usually of the order of -5 to +5 centimetres of water. Air is slowly introduced until low positive readings of approximately +5 +10 centimetres of water are obtained. The requisite volume of air varies between 80 and 200 millilitres, but is of secondary importance to the pressure readings. The initial refill is almost invariably attended by some chest pain and tightness. Some reassurance and the administration of a small dose of omnopon suffice to control this.

Further aspirations and refills are regulated by frequent screening control. On an average a total of four to five aspirations and 10 to 14 days suffice to dry the space. At each aspiration the antibiotics are introduced and each refill gradually raises the pressure readings until, at the end of a fortnight, the terminal figures reach a level of approximately +25 +30 centimetres of water. Cleland (1948) after describing the characteristics of the lateral costal branch of the internal mammary artery recommends aspiration and refill of the space by a posterior route to avoid laceration of the artery or one of its venae comites. In several hundred refills and aspirations, this accident has not occurred in our patients. With the space dry and adequately established, the long term management of the extra-pleural pocket renders itself into

a routine of regular screening examinations and refills at seven to 14 day intervals. The technique of refilling is basically similar to that described for aspiration. The position of the patient and the site of entry are identical. No local anaesthetic is employed as an artificial pneumothorax refill needle of the Saugman type can readily and rapidly be inserted without much discomfort on the patient's part. Indeed, having experienced previous injections of local anaesthetic, the patient frequently remarks on the absence of pain and elects for the non-anaesthetic procedure. A Maxwell apparatus is again used to record pressures and administer air. As in aspiration, the sensation of 'give' and the recording of swinging pressures, announce the entry of the needle into the space.

In contrast to the selective relaxation collapse of intra-pleural pneumothorax therapy, the effect of an extra-pleural pneumothorax depends on an active, positive pressure compression of the diseased lung over a limited area. Thus a typical end pressure reading may be of the order of +35 +45 centimetres of water. At the commencement of insufflation, the initial reading should ideally be in the vicinity of +10 centimetres of water. A sliding scale of positive pressures is thus maintained in the space between refills. This comprises the basic management of extra-pleural pneumothorax treatment. The amount of air injected is of much less importance than the pressure readings

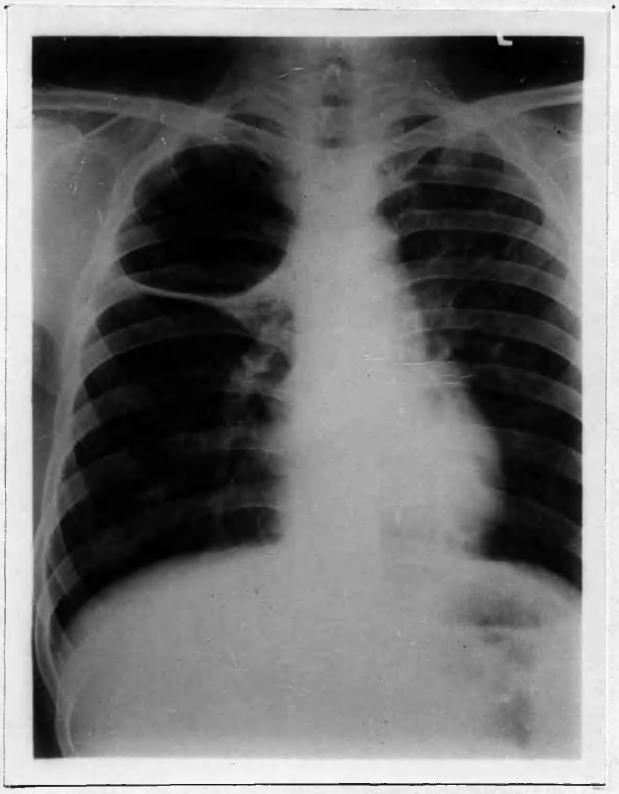


Fig.10.

achieved and varies fairly widely between 80 and 180 millilitres. Satisfactory pressure maintenance can be confirmed at fluoroscopic examination. The space should have a somewhat 'cannonball' appearance and its lower border should be concave in an upward direction. Fig. 10. shows the typical radiological appearances. The main indication that refills can be extended, first to 10 day and then to 14 day intervals, is seen when the space pressures recorded at the commencement of a refill show a healthy degree of positivity. Readings of +15 +25 centimetres, coupled with satisfactory x-ray appearances would allow a gradual extension of the inter-refill period. Usually such an extension is not even contemplated until the pneumothorax has been in progress for two to three months. Proctor (1940) describes the use of excessively high pressures ranging up to 130 centimetres of water. He worked on the principle that to prevent the lung re-expanding it was necessary to pump in the same amount of air each time practically irrespective of pressure readings. In the light of our experience and the remarks just made, this concept is basically fallacious. When steady, positive pressures are maintained there is no apparent tendency for the lung to re-expand. In addition, because of the danger of rebound air embolism, which is referred to in the following chapter, the practice is potentially dangerous.

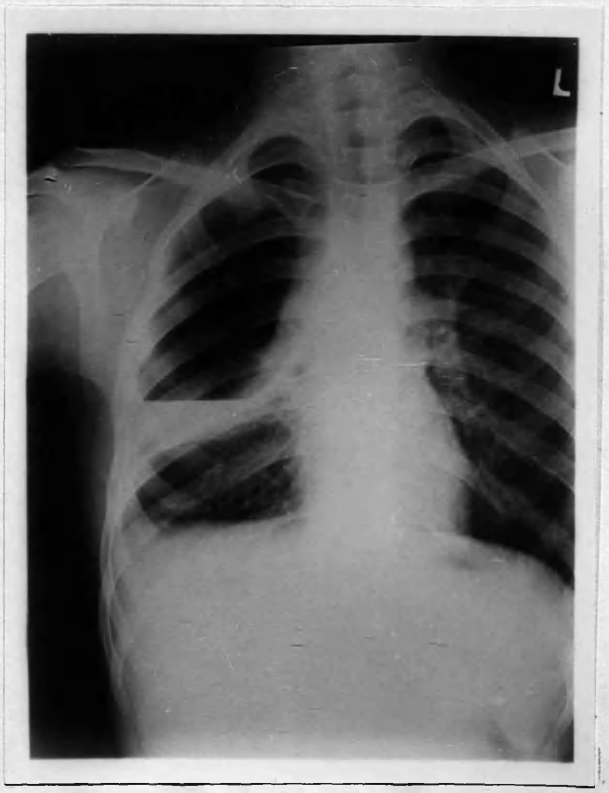


Fig.11.

D. Variation in Space Size.

The gradual extension of the inter-refill interval to a period in excess of a fortnight is resorted to only on comparatively rare occasions. In such patients, the reason for the unduly long interval is usually a space of somewhat larger dimensions than the routine tight selective pocket. At first glance the variance of space-size seems impossible when each patient is subjected to a standard stripping procedure. Differences in size, rise however in two main ways. The inevitable post-operative haemorrhage, if occurring on a somewhat larger scale than usual, can cause in some patients, by reason of the sheer weight of fluid collection, a definite progression of the separation of the lung beyond the limits already described. Fig. 11. shows the final volume of the space in a boy who sustained a moderately severe post-operative haemorrhage complicated by clotting. After removal of the clot the space can be seen to extend posteriorly to the level of the ninth rib. The initial mobilisation of the lung conformed to the usual standards.

The second explanation of variation in space size is to be found in the general configuration of the thorax. In the short sthenic type of individual with almost horizontal ribs the vertical extent of the space is smaller and the space itself appears correspondingly less voluminous.

Fig.12.

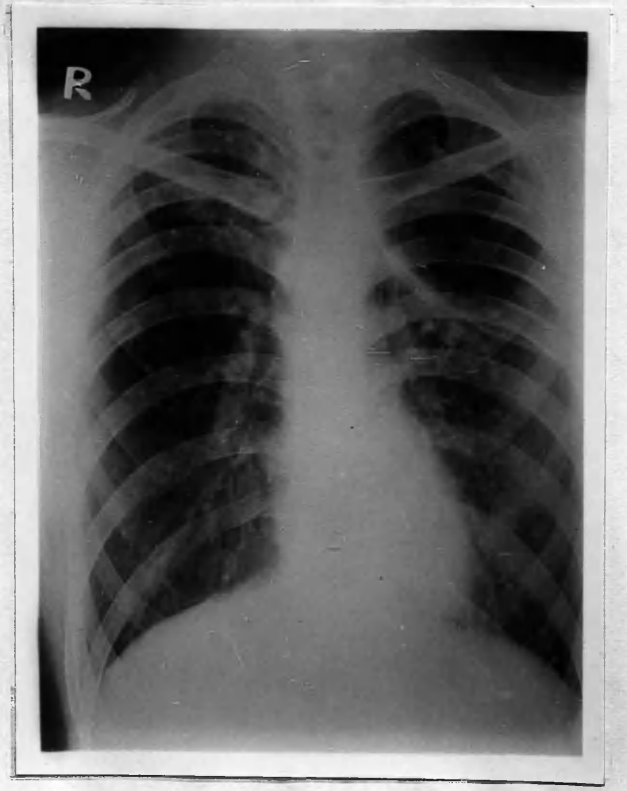


Fig.13.

When the thorax is longer and more funnel-like, with downward sloping ribs, the increase of vertical measurement of the space makes it appear much larger. Fig. 12. shows a standard pocket in a sthenic patient and Fig. 13. a similar space in a more elongated thorax.

In both these patients the pneumothorax is equally effective in achieving disease control and the only difference in management is that different amounts of air are required to produce equivalent pressures in each space. By and large, the more voluminous the space, the lower the optimum maintenance pressure required and the stronger the possibility that refills may be less frequent. An effective end reading in a large pocket is usually in the vicinity of +25 +30 centimetres of water - 10 to 15 centimetres less than in the standard space. Refills can usually be spaced out to a fortnight and sometimes after several months, as in one or two of our patients, a three week interval can be reached.

E. Defective Anterior Strip.

The importance of clearing the lung adequately anteriorly from the first and second interspace at the time of operation has been stressed already in the description of operative technique. In some of our earlier cases this anterior limit of the strip was not so meticulously pursued, with the later result that refills administered from the

front became complicated by the presence of an anterior tongue of lung covering the second and sometimes the first intercostal spaces. The line of pleural reflection, adequately low in the axilla, climbed obliquely upwards as it passed forward to the sternum. As a result, a refill needle inserted in the usual mid-clavicular line had to pass through the lung itself and the investing pleural layers behind it before reaching the space. To obviate this, the site of refilling in these cases was moved further laterally between the first and second ribs and if this was still unsuccessful a position high in the axilla was used. As a last resort the paravertebral route was employed and all those defective spaces have been successfully continued without incident to date. The lung in each case had been efficiently mobilised posteriorly and as the posterior segments of the upper lobe are the ones usually involved in the disease process, the spaces which were ultimately stabilised and maintained, were fortuitously, the most selective in the series.

The compression of the lung, so effective posteriorly, spared the undiseased lung tissue in front. A defective anterior strip is recognisable in an ordinary postero-anterior film of the chest. Two lung levels are seen. The lower, more definitive one, represents the posterior, and thus the basal limit of the space. Above this is a zone,

more translucent than normal lung parenchyma, but with tracings of lung markings visible in it and a faint but definite upper limit. The upper line represents the anterior line of the parietal pleural reflection and the hazy area between the lines is really the process of lung tissue coming up in front of the space. A lateral plate very effectively shows this rising obliquity of the pleural reflection from the rear, forward towards the sternum. The following case report illustrates these points.

Case Report:- No.23. The patient, a female aged 25 years, was admitted to Mearnskirk Hospital in April, 1950. After a preliminary unsuccessful attempt at artificial pneumothorax induction, a left extra-pleural pneumonolysis was carried out on 8th June, 1950. An apparently satisfactory strip was achieved and the post-operative course was uneventful. She was transferred out of our hands to her original ward, 12 days after operation, with a dry and established space. In the course of the following six weeks she was referred to the unit several times because of difficulty in refilling the space. After postero-anterior and lateral radiography and investigation of the most efficient site for refills, the existence of an anterior process of lung tissue was realised. She was the first patient in which this had been observed. Axillary refills were instituted and have been maintained without incident for the last 15 months. Postero-anterior and lateral

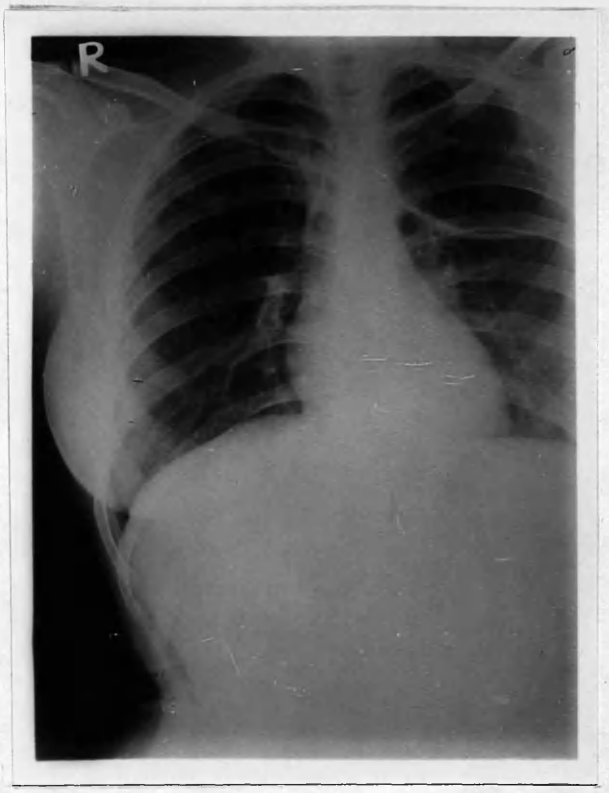


Fig.14.

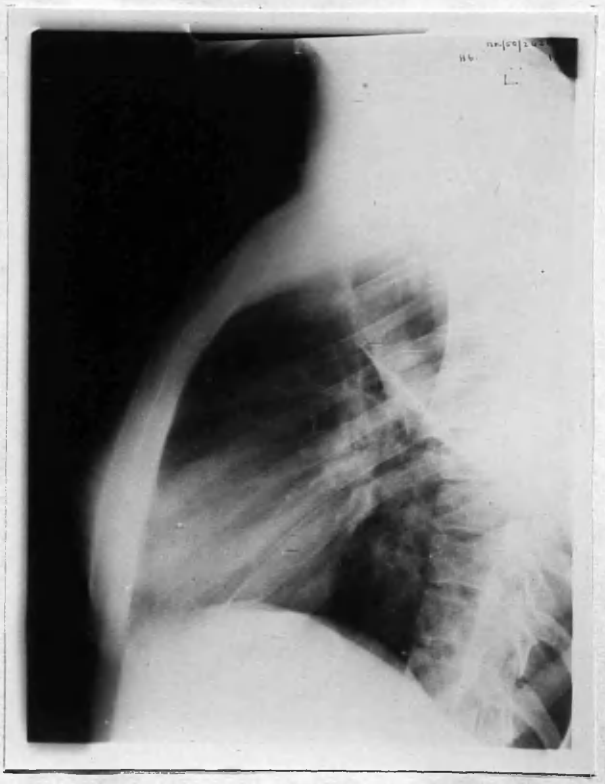


Fig.15.

skiagrams of her chest are reproduced in Figs.14. and 15 . The postero-anterior film shows an apparently satisfactory normal air-pocket with a concave inferior line which really represents the posterior limits of the strip. Above it is a more translucent area with a faint upper limit crossing the first interspace. The lateral plate shows the oblique sharply rising lower extremity of the space. By changing the site of refills, the girl has has an effective compression of her disease maintained for over 15 months, after a phase of trouble which almost caused abandonment of her pneumothorax. She is in excellent condition today with repeatedly negative sputum and a B.S.R. of 5 millimetres in the first hour (West.).

This interesting facet of extra-pleural refills may account for such reports as that of Hoffman and Kettler (1943) who routinely employ oil to fill the space because of inevitable difficulty in maintaining air refills. The persistence with anterior refills, of course, in the face of such difficulties, leaves the way wide open for the dangers of air embolism or tuberculous space infection, as a result of the repeated needling of the lung. Several of our earlier cases are now routinely filled by the axillary or paravertebral routes and their spaces have been satisfactorily maintained for long periods in this manner.

F. Post-Operative Sanatorium Treatment.

To achieve maximum benefit from the operation it is

essential to consolidate its gains by a period of sanatorium treatment. The duration of this sanatorium aftermath cannot be stated with accuracy. It varies quite naturally from patient to patient and depends very largely on initial general condition, state of contra-lateral lung, efficiency of collapse, etc. In the straightforward case with disease limited to one upper lobe, effective disease control is rapidly attained within a few weeks. Recovery from operation is encompassed within a similar period and the only requisite for the maintenance of this desirable condition, is the continuation of appropriate pressure refills. In such cases, a period of six to eight weeks bed-rest and toilet regime usually suffices and can then be followed by progressive mobilisation on the usual sanatorium lines. At the end of 12 to 14 weeks these patients are quite fit to proceed home to attend for out-patient refills. Indeed many of them show a most dramatic improvement in general well-being even in that comparatively short time. The erythrocyte sedimentation rate falls steadily to normal levels, the sputum reverses rapidly and the weight shows a steady gain.

In the face of more extensive disease, this phase is correspondingly lengthened. If the disease is bilateral, the institution of an extra-pleural pneumothorax on each side however can produce disease control in both lungs within a surprisingly short period. One of the worst risk

cases in this series, with bilateral fibrocavernous disease of 11 years duration, contrived to leave hospital in a very fit condition only six months after his bilateral operation. The great majority of the patients, completing their post-operative phase at Mearnskirk, were dismissed within four months.

During this time also, the 90 gramme course of streptomycin is completed with the usual P.A.S. accompaniment. It has been our practice to continue the P.A.S. in the increased dosage of 18 grammes per day after the cessation of streptomycin and until the patient is dismissed. Thereafter, it is usually abandoned.

G. Conversion to Oleothorax.

In some patients the extra-pleural pocket proves to be either difficult or even dangerous to maintain by means of air refills. Some of the spaces, though initially adequate and completely dried, show a tendency to gradual but inexorable obliteration. To increase the pressure of refills in these circumstances in an attempt to arrest this process is futile. With gradual progress of the obliteration, lung tissue may eventually creep upwards and occlude the usual first intercostal site of refills. Air must then be administered by either the axillary or paravertebral routes. At this stage, however, before further re-expansion vitiates the disease control achieved by the operation, it has been

found useful here to replace the air with an inert sterile oil filling and thus obviate the necessity for further, regular difficult refills. Such circumstances have arisen in eight of the patients in this series and this variety of oleothorax has been called the anti-symphiseal type by Schmidt (1938).

Replacement by oil may also be desirous under different conditions. In some casea a sterile effusion persists in the space despite repeated aspirations. Radiologically the walls of the space become progressively thicker and when a needle is introduced for refill purposes the leathery consistency of the tissue is obvious. The possibility of those patients progressing to frank tuberculous empyema can be forestalled by the timely insertion of oil. This is the disinfection oleothorax of Schmidt and was required on three occasions in our patients.

Of these eleven patients, nine are alive and well with adequate disease control. One patient is deteriorating steadily and one male patient died 17 months after operation. Both these latter cases had advanced bilateral disease and in each the extra-pleural pocket was from the start inadequate. Gradual dwindling of the space necessitated the oil replacement. There have been no broncho-extra-pleural fistulae and all the spaces have been maintained successfully. Liquid paraffin was employed in our first four cases and olive oil in the final seven. The mineral

oil has the advantage that there is little, if any, absorption of it by the tissues. Periodic replacement is therefore unnecessary. Its two disadvantages are its tendency to cause moderately severe influenzal-like reactions at the time of insertion and the possibility of the later formation of a paraffinoma of either space or wound. All four patients receiving paraffin had pyrexial reactions after the introduction of the oil. In one young male patient the liquid paraffin later herniated from the extra-pleural space into the subcutaneous tissues in the region of the wound. Presumably the effusion, excited by the presence of the oil, so increased the space pressures that an outlet became necessary. Fortunately the wound provided the safety valve and no fistula resulted. The subcutaneous oil was aspirated and the oleothorax was continued without further incident. This man now has a small symptomless paraffinoma of his wound.

Olive oil, on the other hand, is free of unpleasant side reactions but appears to have the disadvantage of being very slowly absorbed. The seven replacements with this oil have all been uneventful.

Oleothorax is referred to frequently in the literature. Mayer (1913) referring to Baer's use of a mixture of paraffin, lipiodol and vioform, calls it 'surgical gruel'. In two animal experiments he contrived to produce gangrene of the lung in one and a fistula in the other. In his first article

in 1936, Graf converted all his 34 cases to oil. Proctor (1940) converted the majority of his cases to oil and used olive oil with two per cent gomenol. In four years experience he had no complications. Hoffman et al (1943) used oleothorax routinely as they found air refills difficult to maintain and with air maintenance, space infections and obliteration were frequent bugbears. Dolley et al (1940), sifting the results of their world-wide review of extra-pleural pneumothorax, record that the consensus of opinion considers that oil conversion is required in the majority of cases. From a communication by Adelburger et al, who had continued large scale extra-pleural surgery after Schmidt's untimely death, they reported that of 544 cases to May, 1939, 57 per cent had oleothorax. In 1949 Friedman and his colleagues expressed some doubt as to the advisability of placing an oil in the space. Twenty-four per cent of their cases were converted and four out of five broncho-pleural fistulae in their series occurred in the oil-filled spaces. The tuberculous empyema rate also appeared to be much higher when oil was used. They therefore avoid conversion to oleothorax whenever possible.

Among the cases reported here there have been no instances of broncho-extrapleural fistula or tuberculous empyema. It is felt that an important factor in avoiding such catastrophes is the timing of the insertion of the oil. Replacement is never resorted to early in the course of the

pneumothorax. An adequate trial of air refills is routine and it is only after the passage of some three to six months that conversion to oleothorax is considered. None of our patients have had oil inserted earlier than three months after operation and in the majority the time lag is nearer six months. This interval allows the lining membrane of the space to become thickened and therefore more capable of safely containing the oil. In addition, the space has successfully weathered the immediate post-operative period and its efficacy as a method of disease control can be accurately assessed. Cutler (1951), after deprecating the insertion of various inert plombes at the time of operation, goes on to recommend that if oleothorax is desirable it is best accomplished six to twelve months after operation, when the early dangers of space infections, etc., have been successfully passed. By this time the extra-pleural space can be allowed to dwindle partially until the collapse is limited entirely to the diseased area as it then appears. The introduction of a mineral oil at this stage is purely a replacement therapy to maintain the very highly selective collapse already established. It must be remembered that the extent of Cutler's standard pneumonolysis is more extensive than the one employed here and he therefore had more scope for allowing partial obliteration to reduce the pocket to more selective dimensions. The most important feature, however, is his timing of oleothorax conversion.

Although his time lag is double the one in this series and his reasons for postponement are slightly different, his results with oleothorax, like those in the patients reported here, appear safe and satisfactory.

The actual technique of oil conversion is relatively simple. The first intercostal space is again utilised, if not occluded by re-expanding lung tissue and the patient, as at refill, is once more placed in the supine position. Two needles are inserted. The usual long aspirating needle is passed into the space until it abuts on the posterior chest wall. By withdrawing it about half an inch, its tip is left in the paravertebral gutter and it is then in optimum position for the delivery of the oil. A shorter needle is also manoeuvred into the space alongside the first, but only till its point has just entered the pocket. This needle serves as an air outlet and prevents undue rise of extra-pleural pressure while the oil is being introduced. Satisfactory filling is indicated when oil begins to ooze from the safety-valve needle. A small space requiring 60 - 100 millilitres of oil can be safely filled at one sitting. Larger pockets may require two or even three sessions. Complete filling is not the object, as the inevitable sequel of the oil in the space is the excitation of a small effusion. A small residual pocket of air by its ultimate absorption safely makes way for the effusion and this fluid added to the oil supplies the ultimate complete

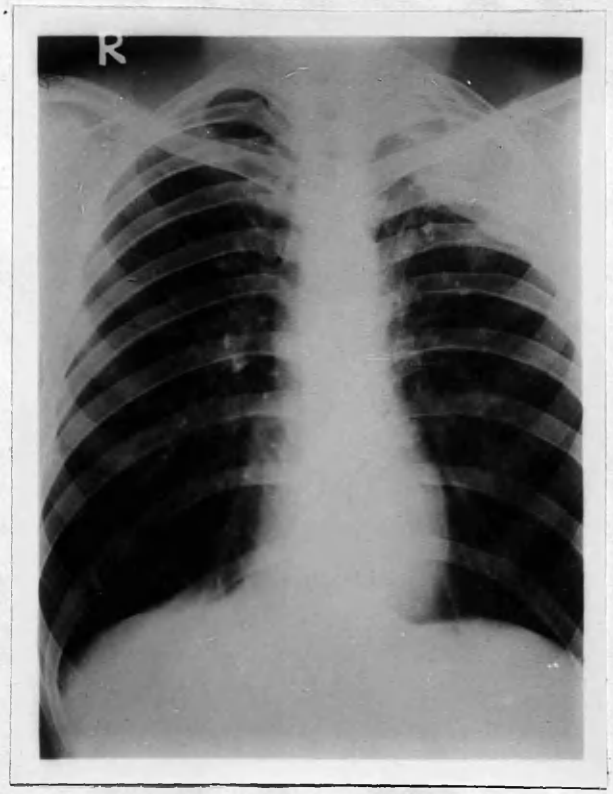


Fig.16.

space filling. During the two or three months which follow, the fluid component is gradually absorbed with some concomitant slight reduction in space size. Fig.16. shows the end result in Case No.13. The extra-pleural pneumothorax was performed on 10th May, 1950 and conversion to liquid paraffin filling was effected on 9th August, 1950. A pyrexial reaction of gradual dwindling severity followed during the next seven days. The x-ray reproduced here was taken at follow-up in October, 1951. The patient is in very good general condition, his disease is calcified and he is working full time.

* * * * * * *

CHAPTER FOUR.

COMPLICATIONS.

1. PREFACE.

Before embarking on this chapter, it is, I think, essential to point out one of the unique features of this series of cases which effectively separates it from any of the earlier reports on the subject of extra-pleural pneumothorax. An extensive review of the literature reveals no evidence of a similar survey in which routine antiobiotic and chemotherapeutic cover was used in an attempt to re-evaluate the place of the operation in the treatment of pulmonary tuberculosis. Of the two major reports on the subject which have appeared in 1951, the first by Murstad covering 600 cases operated on up to 1947 made no mention of streptomycin or P.A.S. but commented on the value of penicillin. The second, by Cutler, is probably the only account which is roughly comparable with the present one. Of his series, however, of 129 operations in 121 patients, only approximately half were covered by the antiobiotics. The much improved results produced by the advent of these drugs he describes with enthusiasm and refers to the "vital difference" they have made in extrapleural surgery. Part of the improvement he also attributes to better selection of cases and improved operative technique.

This reassessment of extra-pleural pneumothorax, however,

is the only one in which every patient has had the benefit of the protective antibiotic cover. The accounts, therefore, of both complications and results are only strictly comparable with those recorded in earlier series in so far as the beneficial influence of streptomycin, penicillin and P.A.S. is concerned. Despite the formidable array of complications described by the earlier authors, many surgeons were attracted to extra-pleural pneumothorax as an operation, and many accorded it a place, even if only a limited one, in the treatment of the pulmonary disease. The main bugbears which prevented a more extensive application of the procedure, were space infection, bronchogenic spread of disease and haemorrhage.

2. FATALITY.

A. Operative Fatality.

In the 105 operations under consideration there has been no instance of an operative death, despite the fact that some of our patients were extremely poor risk cases. The figures of other authors are somewhat difficult to interpret because of divergent estimates of what constitutes an operative fatality. Roberts (1948), for example, takes a very literal idea of the term and includes post-operative space complications contributing to death and occurring up to one and a half year's later, in reaching his total of 14 per cent in 100 cases. Sullivan (1948) refers to 'early' deaths within the first six weeks and records four in this category after 92 operations on 82 patients. Reid (1946) had one

operation death and four fatalities soon after operation due to bronchogenic spread of disease. Barret (1946) quoted by Reid had no deaths in 38 cases over a period of four years. Arnold et al (1946) records nine 'immediate' deaths and Simmonds (1941) had seven 'operative' deaths in 44 patients.

These widely divergent figures illustrate the difficulty with this operation in apportioning the blame for a fatal outcome. Many authors include serious space complications e.g. bronch-extrapleural fistula and tuberculous empyema as cases of 'late' deaths. Murstad (1951) in his definition of an operation death includes those with a plausible causal connection, even if the patient has been discharged and regardless of time. With extra-pleural pneumothorax this seems to be a more correct approach and brings into proper perspective the potentiality of the operation to cause death after a long interval. The limitation of the relatively short follow up in our cases in assessing this potential fully, are realised. At the same time it must be borne in mind that the serious complications which could cause death, formerly occurred relatively early in the post-operative course and that late disasters were rare. (Newton et al, 1940.)

B. Late Fatality.

One of our patients (1 per cent), Case No.5., died eighteen months after operation. He was from the outset an extremely poor risk, having suffered from bilateral, fibro-caseo-cavernous disease for five years. Previous artificial

pneumothorax, phrenic crush, artificial pneumoperitoneum, and oral P.A.S. were among the measures which had proved unsuccessful. Breathlessness, on even slight exertion, was a feature due to progressive diminution of functioning lung tissue. A left extra-pleural pneumothorax was performed on 5th April, 1950 but a combination of defective mediastinal mobilisation and timorous post-operative filling resulted in only a small inadequate space. He weathered the operation successfully and for a few months managed to achieve cavity closure in his left upper lobe. In late 1950, however, his cavity re-opened and very slowly his general condition started to deteriorate. The radiological appearances of his disease showed little change and ultimately, in October 1951, he died quite suddenly after a moderate haemoptyses which precipitated cardiac failure.

To compare this lone death with figures for late fatalities reported elsewhere, is unfair in view once more of the relatively short follow-up. In this centre it is felt, however, that these early minimal fatality figures will be reflected later on in considerably reduced overall mortality rates.

3. MORBIDITY.

For ease of description the complications attendant on this operation can be considered under three main headings.

1. Complications encountered at operation.
2. Complications occurring early in the post-operative course.
3. Complications occurring late in the post-operative course.

A. Complications encountered at Operation.

Proctor (1940) describes five operative pitfalls which can occur - "puncture into a cavity", "tear into the free pleural space", "haemorrhage", "rapid compression of the diseased lung", and "pyogenic infections". He then goes on to relate that the latter three of these dangers have not been observed in his cases. The experience gained here has been very similar and tearing of a thin parietal pleura or damage to the lung parenchyma have been the surgeon's major pre-occupations.

1. Damage to Lung Parenchyma.

Minor damage to the lung substance has occurred once in this series. (Case No.69). It has already been referred to briefly in the section on Operative Technique. During the course of a difficult strip, the lung was denuded of both pleural layers over a very small area and some damage to the superficial alveoli resulted. Inflation of the lung by the anaesthetist under some pressure produced a few bubbles of air at the damaged site but a standard apicolysis was completed. The date of operation was 25th January, 1951. The post-operative course was uneventful and the space has

been maintained by air refills to the present date with an excellent general result on both disease and patient.

Actual cavity rupture has not been encountered at any stage in those operations but the possibility of such a disaster occurring can be readily imagined when gross excavation of the upper lobe and dense overlying peripleuritis co-exist. The mobilisation of the apex under those circumstances must be painstakingly carried out and is fraught with difficulties. Murstad (1951) who reports cavity rupture in six cases (1 per cent) thinks that some could have been avoided by better technique or by abandoning the operation entirely. He adds "but I do not think one can completely avoid this calamity without being too cautious, abandoning too many pneumolyses." Most surgeons describing the catastrophe echo these remarks regarding the preventive value of better operative methods and complete abandonment of the difficult operation. Should actual cavity damage occur, the unanimous opinion is that the operation should be stopped forthwith. Attempts to repair a ruptured cavity wall are futile. Some authorities convert the operation to a formal thoracoplasty immediately, while others, e.g. Dolley et al (1940), recommend that the wound be packed open after resection of the upper three ribs. More recently, Berard et al (1948c) has recommended emergency lobectomy before tuberculous soiling of the space occurs. He describes the very superficial cavities which are prone to

rupture and comments on the hopelessness of suturing the pathological tissue which comprises the walls. An account of one case is given in which lobectomy was performed the day after the cavity was opened. An uneventful post-operative course and a satisfactory outcome followed. Marmet (1949) reports a similar case and also advocates immediate excision in these circumstances. Berard et al (1949) describing the place of lobectomy in extra-pleural pneumothorax treatment, has obviously continued with this emergency treatment which he advocated first in 1948, for he now mentions three patients treated in this fashion. This would appear to be the logical remedy for a torn cavity, if, as Berard says, the cavity is localised to the upper lobe, the base is healthy and the contralateral lung is free of disease. Failing some such effective treatment, a cavity opened at operation by providing an immediate broncho-extra-pleural fistula, leads the way to tuberculous broncho-pneumonia and ultimate death.

2) Tear of the Parietal Pleura.

a) Pre-Operative Assessment of Intra-pleural Space.

This apparently trivial complication has proved to be one of the most irritating bugbears in the present series. One small rent in the parietal pleura can vitiate all the advantages of the operation. It is impossible to assess accurately by radiography before operation, the thickness of the pleura or the extent of the symphysis between the layers.

Gross pleural thickening is, of course, obvious but such marked changes are more the exception than the rule. The expedient of exploring the intra-pleural space with an artificial pneumothorax needle does not always afford accurate evidence. No satisfactory space pressures may be recorded at the site of entry and yet the lung may be widely free in its basal parts. Even the prior existence of an artificial pneumothorax itself does not always lead to extensive obliteration of the pleural sac and several of our patients, having had previous pneumothorax treatment, demonstrated at operation quite extensively free spaces over the lower half of the lung. The only comfort to be derived in such cases is, that probably the dome of the lung,at least, will have a firmly adherent pleural cap. At the other end of the scale there are the patients who present with limited upper lobe disease having had no active interference, and yet, who, at operation are found to have a completely obliterated space - a relic of some previous intense pleural reaction.

Because of these pleural vagaries it is now our custom to assess the sac by attempting an artificial pneumothorax induction. The space pressures are recorded before and after the introduction of a limited quantity of air and a rough assessment of the extent of the sac is made. If no satisfactory pressures are elicited the surgeon can have hopes of a reasonably straightforward operation. If a free space

seems to be present, at least he is forewarned of the necessity for extreme care. Tentative thoughts are also being directed towards the production of a preliminary artificial pleurodesis to circumvent this difficulty.

b) Incidence of Tears and Management of Combined Space.

A tear of the parietal pleura occurred in no fewer than 21 (20 per cent) occasions in the 105 operations under review. This total includes those tears actually seen at operation and also several 'invisible' rents which were evidenced by the presence of intra-pleural air seen in post-operative skiagrams. In seven patients it was observed that the tear communicated with only a very limited intra-pleural space. These patients had no significant collection of air in the pleural sac post-operatively and their management was in no way different from the straightforward untorn case. In 14 patients, however, the lung was widely free over its lower half. The management of these patients is complicated by the fact that it is impossible to maintain positive pressures in the extra-pleural space, due to the air dissipating itself at refill through the defect in the parietal pleura into the intra-pleural sac below. The underlying lung frequently becomes atelectatic and the normal post-operative sanguineous effusion gravitates to the base. The object is to hasten re-expansion of the collapsed lung by diligent aspiration of blood and air from the pleural space and thus hasten obliteration of the rent in the pleura by the re-expanding lung itself. During this manoeuvre,

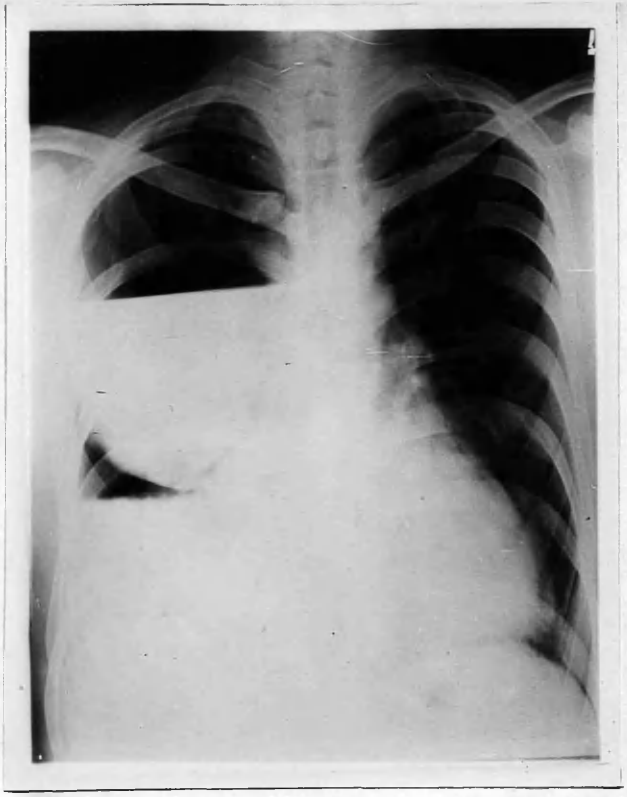


Fig.17.

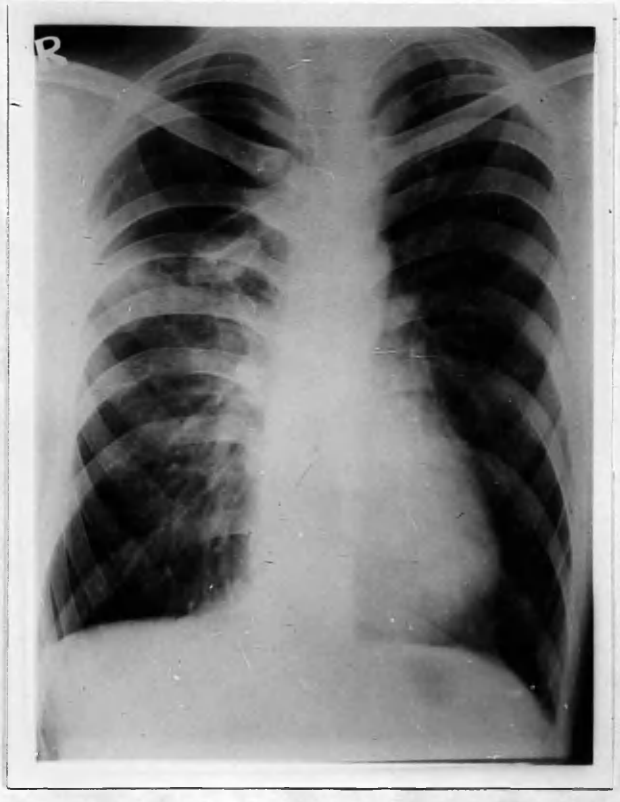


Fig.18.

which may occupy 14 to 21 days, the extra-pleural compartment has to take care of itself. Any attempt to refill it merely perpetuates the space below. Fig.17.shows the usual post-operative picture in such patients. This man, fortunately, had a large collection of extra-pleural blood which was left undisturbed and maintained the pocket while all efforts were directed to exhausting his intra-pleural space of blood and air. The right lung is atelectatic and a deep intra-pleural pneumothorax with a large basal pool of blood is present. Fig. 18.shows the end result after re-expansion of the lung and obliteration of the inter-space communication. The extra-pleural pocket has dwindled to a slight extent but is otherwise satisfactorily maintained with adequate disease control.

Five of the 14 patients mentioned above, in addition to having free pleural spaces, also sustained massive clotting of the blood effused into the extra-pleural compartment. This fortuitous complication proved a blessing in disguise. The clotted blood maintained the operation space until removed surgically at the end of three weeks. By this time the underlying intra-pleural pneumothorax,with its inevitable sanguineous effusion, had been removed and the lung re-expanded. An additional repair of the tear was effected by the deposition of fibrin from the blood clot and all these patients had uneventful courses after removal of the coagulum.

c) Site of Tear.

The site of the parietal tear is also of importance. A small perforation over the apex of the lung is readily obliterated by pressure refills or effusion and rarely gives rise to an extensive combined space. A tear, however, in the gutter of the space near the line of pleural reflection is readily held open and perpetuates the inter-space communication.

d) Implications of the Combined Space.

Most reports in the literature refer to pleural tear as an operative complication, but many writers go on to condone this occurrence by extending the tear in the pleura with the resultant deliberate production of a complete, combined space. Indeed Mayer (1913) expresses a preference for this manoeuvre. In this series there were three main reasons for avoiding the combined operation:-

(i) The large space formed provided an extensive sump for massive and dangerous haemorrhage.

(ii) The immediate loss of the operation's selectivity of action.

(iii) The report of Roberts (1948) which records a tuberculous empyema incidence of 28 per cent in the combined operation, compared with 10 per cent in the standard procedure.

As a result only one semi-accidental combined space was produced at operation (Case No.88) and this patient, by coincidence, has done extremely well. The collapse has now

been satisfactorily maintained for a period of nine months, in a manner similar to a straightforward intra-pleural pneumothorax - the aim of the refills being to maintain a low negative pressure in the space. It is felt that this satisfactory outcome is largely due to the efficacy of streptomycin as operative cover and to the policy of maintaining a relaxation collapse rather than a compression one. When a deliberate extension of the pleural tear is avoided and the main stress is placed on the salvage of the extra-pleural space, it would appear from our experience that damage to the parietal pleura weighs against the chances of prolonged successful maintenance of the space with air refills.

Table No. 4. below shows the ultimate fate of the space in the 14 patients who had a widely free intra-extra-pleural communication.

TABLE NO. 4.

FATE OF SPACE AFTER PLEURAL TEAR.		NUMBER.
Extra-pleural Space 'Combined' Space	Maintained by air refills.	6 3 (64.2%)
Converted to Thoracoplasty		3 (21.4%)
Converted to Oleothorax		2 (14.4%)
TOTAL:		14 (100%)

This total of nine patients (64.2 per cent) maintained with air refills, compares with the overall figure for the

remaining 91 operations of 68 (74.7 per cent) air filled spaces.

B. Complications Occurring Early in the Post-operative Course.

1). Post-operative Haemorrhage.

a) Introductory Remarks.

By the very nature of the dead space produced at operation, a certain amount of post-operative haemorrhage is the rule. In varying degree, it occurred in every one of our patients and was fully expected, usually small in amount and readily dealt with by energetic aspiration. Most accounts in the literature make only scanty reference to the problem and many say that the main way of reducing this late bleeding is to achieve efficient haemostasis at the time of operation. The haemostatic methods described vary widely from the calcium alginate of Mullard (1948) to the thromboplastin used by Friedman et al (1949). The use of hot saline packs is almost universal. Mullard's paper reports the use of calcium alginate in 11 consecutive cases and he records that no undue haemorrhage occurred in any of these patients. He reports that previously moderate to massiave haemorrhage occurred in approximately 20 per cent of cases and concludes that this seaweed extract has some value as a haemostatic. The small number of cases involved, however, allows the risk of coincidence to creep in. In this series, where post-operative haemorrhage and clotting have been the most troublesome complications, there have been occasions when 11 consecutive cases have managed to escape.

By and large, however, in previous reports the problem of post-operative haemorrhage has been dealt with in a superficial manner. But if haemorrhage has had only brief mention, coagulation of the effused blood has been almost entirely ignored. Notable exceptions to this neglect are Reid (1946), Head et al (1948) and Gaensler et al (1951). Head describes the unpleasant effects of clotted blood left in the space and advocates removal after a week. Murstad (1951) leaves one per cent sodium citrate solution in the space at the time of operation and renews it frequently during the early post-operative days. He thinks this method reduces the risk of clotting but does not eliminate it. The most outstanding contribution to the problem is supplied by the French surgeon - Bérard (1948d). In an excellent article entitled "Les grandes haemorrhagies du pneumothorax extra-pleural" he subdivides haemorrhage into early and late categories and his experiences closely resemble those encountered in this series.

It may be said at the outset that clotting of the effused blood has been the most troublesome feature in our patients. Major coagulation requiring later operative removal, complicated no fewer than 23 operations (21.9 per cent). Persistent haemorrhage uncomplicated by subsequent clotting occurred in one case only. The patient, No.24 in this series, had the dubious benefit of 10 ounces of 3.8 per cent sodium citrate solution left in his space at the

time of operation. He bled progressively and profusely during the first 15 hours and when aspirated yielded three and a half pints of blood from his chest. A replacement transfusion of three pints produced rapid recovery.

Coagulation therefore has been the major problem. The amount of blood lost is not necessarily excessive and indeed may produce no evidence of exsanguination. Only two of the 23 patients required one pint transfusions and even those were probably not essential. One patient alone was in danger of his life and he, having suffered a late haemorrhage as described below, was endangered more by mediastinal compression than by actual blood loss. Aspiration unaccompanied by blood transfusion saved his life.

For the purpose of description, therefore, the problem of haemorrhage with the bugbear of subsequent clotting, has been considered under the headings of early and late.

b) Early Haemorrhage.

In this variety, the haemorrhage encountered at operation presumably continues steadily either in the form of a generalised ooze or from a slowly leaking vessel during the first 24 post-operative hours. When x-rayed on the first day after operation, the extra-pleural space is seen to be almost totally opaque and exploratory aspiration is unsuccessful apart from yielding a few dark granular clots. The patient himself is not necessarily distressed but tell-tale symptoms of undue chest pain, tightness, and some breathlessness are usually present. Some slight increase in temperature and a

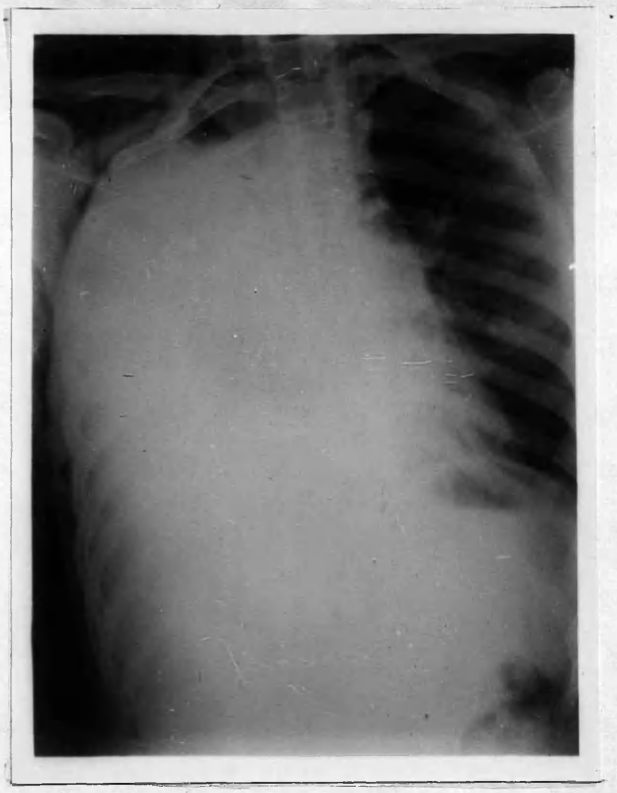


Fig.19.

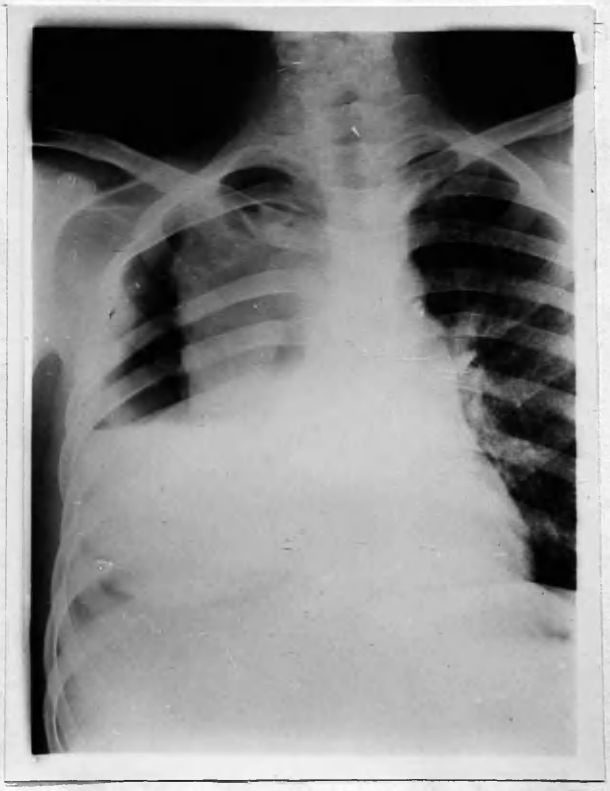


Fig.20.

tendency to nausea are frequent accompaniments. Bérard reports some of these haemorrhages as being aspirable, but in our experience aspiration is only partially successful in evacuating the space and usually considerable clot masses are left behind. The radiological appearances of these patients can be quite startling. Practically the entire affected hemi-thorax may be blotted out by the opacity of the haemorrhage. It is impossible to assess the state of the underlying lung but total temporary atelectasis is a possibility. Over the course of a few days the opacity dwindles in size and eventually becomes limited to the area of the extra-pleural space. Aspiration may be resorted to as such symptoms as pain and tightness require.

Fig.19.shows the post-operative film of Case No.9. who had a massive, early haemorrhage followed by clotting. After various attempts at aspiration and refill the appearances seen were these in Fig. 20 . This was our first experience of massive coagulation and the plate caused some speculation. The radiologist, knowing nothing of the circumstances, reported the dense opacity as "atelectasis of the lung". The space was opened four weeks later and large quantities of unorganised clot removed. There were 22 instances of this major variety of clotting in this series and all recovered without incident. The mode of clot disposal is discussed later in this chapter. Bérard reports the loss of seven patients (1.2 per cent) in a series of 580 cases from this early type of haemorrhage.

c) Late Haemorrhage.

This type is more dramatic and dangerous than the first variety. The operation and the first 24 hours may be totally devoid of incident. The patient is well and the first x-ray film may show only the usual small basal pool of blood. Haemorrhage thereafter commences insidiously and continues steadily until a picture similar to the one described above is produced. The space fills with blood and clotting occurs on a large scale. Bleeding can continue into the clot filled space and a mixture of exsanguination and mediastinal compression ensues. The blood loss is indicated by tachycardia, pallor, etc., but is overshadowed by the pressure on the mediastinal structures. In the fully developed syndrome, the patient is very ill indeed and only determined aspiration of his extra-pleural contents coupled, if necessary, with blood transfusion will save him. If aspiration is initially unsuccessful because of the clotting, the space must be explored from all angles until blood is withdrawn. Should repeated aspiration provide no relief, emergency re-opening of the space would be the only solution. There was only one instance of this dangerous haemorrhage in our 105 operations. Repeated aspiration rescued him from an almost moribund condition without the assistance of transfusion. The clot in his space was removed uneventfully three weeks later.

Bérard, in searching for a cause for these haemorrhages,

has routinely investigated the bleeding and coagulation times pre-operatively but could find no connection between these tests and the amount of blood loss. He also administered vitamins K and C and calcium, but made no impression on the incidence of haemorrhage. One striking feature which he noted in his series of 580 cases, was the notable difference in the frequency of haemorrhage between the sexes. His figures are as follows:-

20 major haemorrhages in males in 180 operations
: 11 per cent.

14 major haemorrhages in females in 400 operations
: 3.5 per cent.

The comparable figures for this series show no such marked sex difference:

14 major haemorrhages in males in 56 operations
: 25 per cent.

9 major haemorrhages in females in 59 operations
: 18.4 per cent.

d) Relation of P.A.S. to Haemorrhage.

These figures, however, do show a considerably increased incidence of undue haemorrhage in our cases. Consideration of the various facets of the problem caused some speculation concerning the potentialities of P.A.S. for producing a reduction in the prothrombin content of the blood. Bavin (1949) investigating various aspects of the compound could find little or no effect in the prothrombin times of rabbits.

Nagley (1949) observed that "although a hypo-prothrombinaemia is usually manifest in those receiving P.A.S., no haemorrhagic tendency has been noted." He does not mention whether any of his patients underwent surgical treatment. Madigan et al (1950) record that with a daily dosage of 30 grammes, prolongation of blood-clotting time occurs within a few days. They also say that oral administration of vitamin K prevents its onset. As a theoretical explanation for our cases it was thought that an extended prothrombin time might allow undue haemorrhage to occur and then with the resultant moderate blood loss the clotting mechanism might once more become effective and cause coagulation in the space. Of the 23 cases showing massive clotting, 14 had received P.A.S. orally, in amount ranging from 12 to 18 grammes per day over periods of several months. The remaining nine had had no preceding P.A.S. or else had stopped treatment with this drug several weeks or months previously. No statistically significant results can be derived from such findings but it is felt that further investigation is worthwhile and routine assessments of prothrombin times during P.A.S. therapy are now being made.

e) Minor Clotting in the Space.

As a result of this high incidence of major coagulation

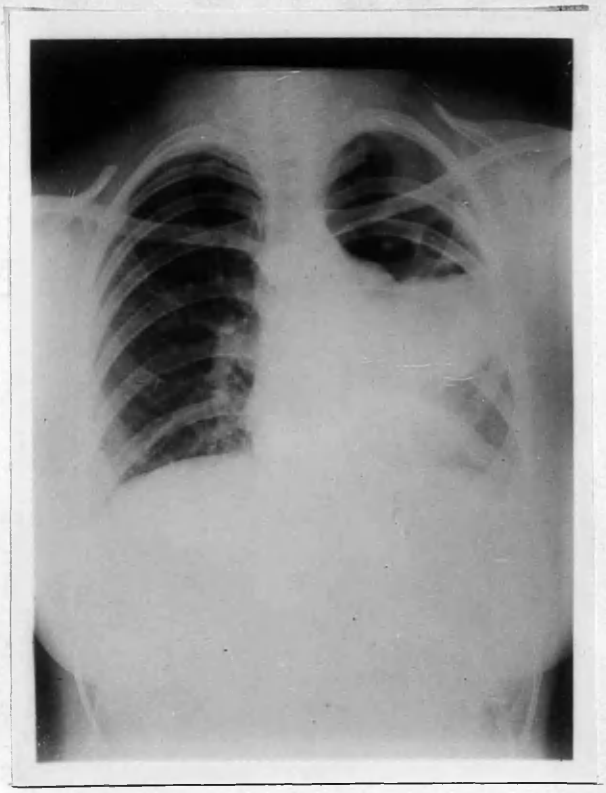


Fig. 21.

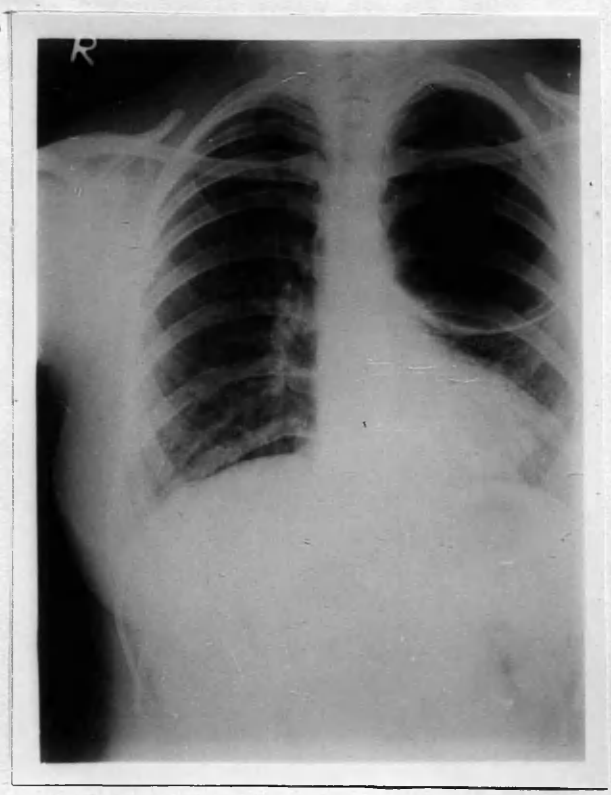


Fig. 22.

a complete review of the post-operative films of every patient in this series has been carried out and the whole position reviewed in retrospect. We had been aware that quite a number of patients showed radiological evidence of minor space clots and that spontaneous resolution of these occurred, presumably due to the production of a fibrinolysin by the leucocytes in the effused blood. The x-ray evidence is difficult to describe accurately but consists in most cases of a slightly reduced translucency of the space as a whole, quite frequently with superimposed annular shadows which sometimes spuriously suggest cavitation. Over and above the 23 patients with obvious clotting, a further 59 were found to show spontaneously resolving coagulum of minor degree adherent to the space walls. The typical radiological picture is illustrated in Fig. 21 . The annular shadows and the general reduction of translucency are well shown. After nine months, the x-ray reproduced in Fig. 22. shows the complete spontaneous resolution which has occurred leaving a clear dry space.

f) Disposal of Clot.

i) Operative Removal.

The clot produced by these haemorrhages requires removal if subsequent infection and contraction of the space are to be avoided. Reid (1946) and Head et al (1948) recommend surgical removal with, in Head's opinion, the end of the first week being the most suitable time. Benda et al (1948)

describe endoscopic methods for removing the fibrin masses. Each of our 23 patients had the space clot removed by a limited surgical exploration under general anaesthesia, at the end of the third post-operative week. The reason for this longer gap was to allow complete healing of the wound to occur before re-entry was attempted. At operation large masses of soft, dark, unorganised clot were removed digitally. There was usually some early evidence of commencing organisation where coagulum was in contact with the chest wall, but in each a large satisfactory space was re-established. These revisionary operations were never followed by undue haemorrhage and indeed blood loss into the re-established space was negligible in every case. Table No.5. shows the ultimate outcome of the space in those 23 patients at the time of follow-up in October, 1951. The comparable percentages for the 82 operations uncomplicated by coagulation are appended alongside. *

TABLE NO.5.

FATE OF SPACE AFTER CLOT REMOVAL.	NUMBER AND PERCENTAGE.	COMPARABLE PER-CENTAGES. *See Text Above.
Air Refills continued	15 (65.20%)	62 (75.60%)
Converted to Oleothorax	2 (8.70%)	9 (10.98%)
Converted to Thoracoplasty	3 (13.05%)	5 (6.10%)
Involuntarily Abandoned (Poor Refilling, Effusion)	1 (4.35%)	2 (2.44%)
Voluntarily Abandoned		
a. Staphylococcal Empyema	1 (4.35%)	1 (1.22%)
b. Tuberculous Empyema	1 (4.35%)	2 (2.44%)
Resection	0 (0.00%)	1 (1.22%)
TOTAL:	23 (100%)	82 (100%)

The patient who sustained the staphylococcal empyema as a complication of the clot filled space is referred to later in this chapter. The infection followed premature re-opening of an incompletely healed wound, with a resultant introduction into the space, of a staphylococcus from a small superficial erosion. From the Table it would seem that the chances of satisfactorily maintaining the space with air refills after the second intervention are somewhat diminished. Five of these patients also simultaneously suffered tears of the parietal pleura with resultant temporary combined spaces. The adverse effect of pleural tears on the prolonged air maintenance of the pneumothorax have already been noted but the additional beneficial influence of major clotting of the space contents in those circumstances has also been recorded. The main factor in reducing the chances of prolonged air refills is therefore the coagulation in the space. The thoracoplasty conversion rate is also doubled.

ii) Enzymatic Removal.

Since May 1951 operative removal of excessive clot in the extra-pleural space has no longer been employed. Instead, the enzymatic action of streptokinase has been utilised to liquefy clot masses and allow their early removal by subsequent aspiration. Although this preparation has been employed in cases outwith the consideration of this thesis, the results have been so remarkably successful that they are thought worthy of mention.

The lytic action of some of the extra-cellular enzymes, produced by the haemolytic streptococcus growing in broth, was first noted by Tillett and Garner in 1933. The full therapeutic significance of the discovery was not adequately exploited, however, until the late nineteen forties. Christiansen (1949) described methods for the purification of three by-products and the name streptokinase was coined for the active fibrinolytic principle. Read and Berry (1950) report the successful clinical use of the preparation in a patient with a clotted haemopneumothorax and in one with a post-pneumonectomy space coagulum. Sherry et al (1950) describe the use of streptokinase - streptodornase in the treatment of clotted haemothorax of post-pneumonectomy and traumatic origin. The results of their enzymatic dissolution of clot were uniformly good. The enzyme is thought to produce its effect by activating a factor present in the euglobin fraction of the plasma proteins. This component, referred to as plasminogen, in turn catalyses the lytic process. The fibrinolytic factor, which is prepared from a non-pathogenic Lancefield group C streptococcus is available in the lyophilized state in which it is both sterile and stable. (Sherry et al. 1950).

In the extra-pleural sphere Cutler (1951) reports that he has recently employed streptokinase to liquefy post-operative coagulum with gratifying results. He makes no remarks on the timing of insertion of the enzyme but observes

that if used too soon in the post-operative period it may induce serious oozing. Gaensler et al (1951) report clotting of effused blood as one of the most troublesome sequelae of extra-pleural surgery. They describe the laudable results produced in three patients by the insertion of streptokinase in the space. Their times for injection were 16, 24 and 43 days after operation and their results with 200,000 unit doses of streptokinase were excellent. The toxic effects experienced by them included fever, urticaria, nausea, and vomiting, but where not unduly prominent in any patient.

The preparation used in our patients contains 120,000 Cathie units in each ampoule. A variable quantity of streptodornase which is not important for clot liquefaction accompanies it. A total of 22 patients have been treated to date with conspicuous success. Such is the ease and safety of the procedure that we now routinely employ it even in patients showing only minimal clot. The time of insertion is, we believe, of considerable importance if insoluble organisation of coagulum is to be avoided. In our first two patients an interval of five weeks elapsed before streptokinase was used but although considerable reduction of clot followed, the walls of each space remained markedly thickened due to the persistence of partly organised coagulum. This five week period has been whittled down steadily until now we inject the streptokinase on the sixth post-operative

day. No aggravation of haemorrhage has resulted and the interval may be still further shortened. It is our custom to inject the streptokinase-streptodornase dissolved in 10 millilitres of normal saline and aspirate the liquefied products some 18 to 24 hours later. A check x-ray is then taken and if any clot persists, a second similar dose is inserted. The great majority of patients, if treated early, respond to one injection with a complete dissolution of clot. Our two five-week patients required three doses each. For clot adherent to the apex of the space we have employed various posturing and rotating methods with good effect.

The usual side effects of enzyme therapy in this type of haemotoma are pyrexia, vomiting, upper thoracic pain, tightness and breathlessness. The temperature elevation is usually beyond 100° Fahrenheit and sometimes climbs several degrees higher. The most troublesome symptoms, pain, dyspnoea and tightness, are due to the inevitable rise in space pressure and may demand an emergency aspiration, especially in an apprehensive patient. In most cases, however, the administration of a barbiturate, combined with tab. codeine co., suffices for pain control. One patient developed signs of an acute arthritis of his shoulder joint 24 hours after the injection of his first dose. The pain was acute and required morphine for relief. His symptoms subsided gradually over three to four days, possibly accelerated by the use of an anti-histamine preparation which was employed in the belief

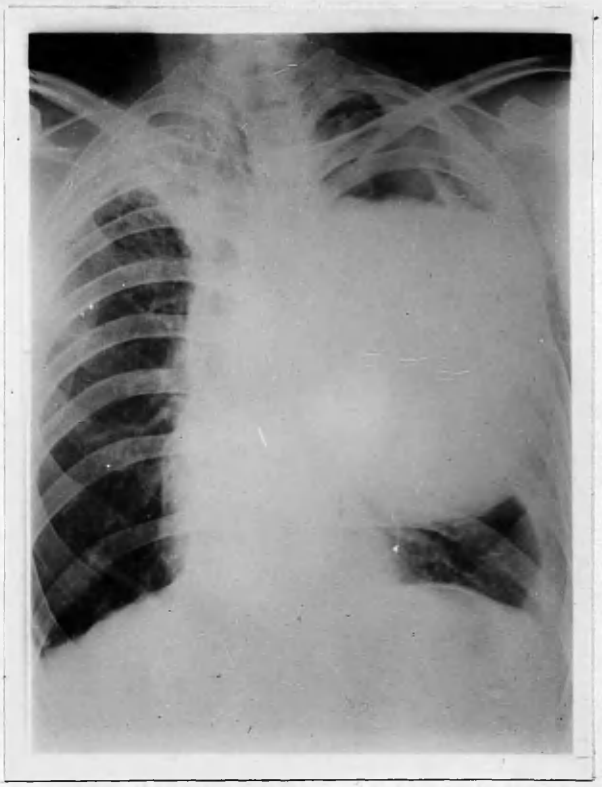


Fig.23.

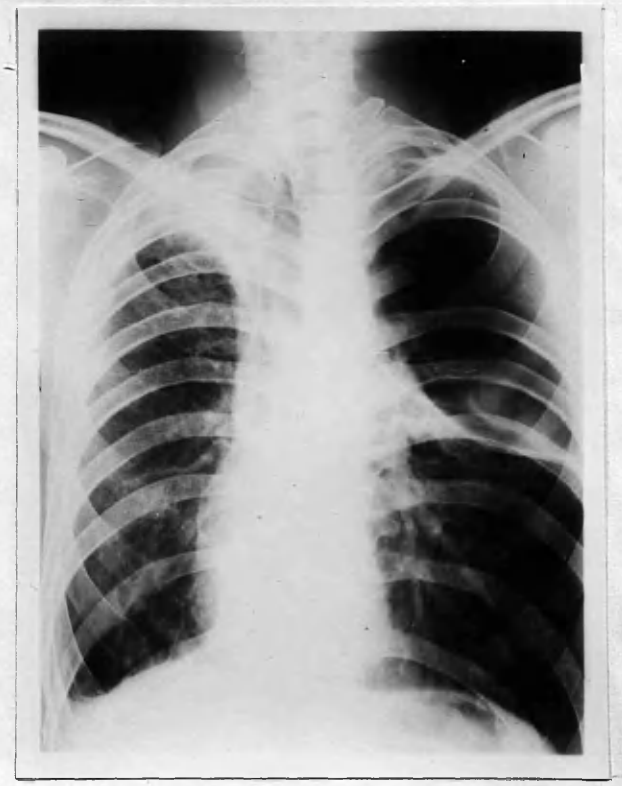


Fig.24.

that the condition was an allergic response.

Figs. 23. and 24. illustrate the efficacy of streptokinase in dissolving massive clot formation. The first plate shows the completely opaque left extra-pleural space and the second the remarkable clearance after injection of two doses of the enzyme. A total of 120 ounces of liquefied products were removed during the course of two aspirations.

2. Atelectasis.

a) Incidence.

Atelectasis has been listed as a complication of the operation more to comment on its benign and frequent temporary nature rather than to describe its disastrous post-operative potentialities. Grigor (1951) has stressed the value of serial, post-operative radiography in diagnosing atelectasis after thoracoplasty. This applies with equal force in extra-pleural pneumothorax. A careful review of all the post-operative skiagrams in this series reveals that atelectasis of the entire lung occurred on nine occasions and that absorption collapse of the diseased upper lobe was obvious in no fewer than 46 patients. This latter figure is to some extent incomplete in that accurate interpretation of post-operative films is sometimes rendered difficult by the amount of the space effusion. This difficulty in assessing the state of the underlying lobe, occurred in only a few cases but instead of hazarding a guess as to the presence of

atelectasis, these patients have been excluded from the total. As can be imagined from the considerable alteration in the intra-thoracic mechanics, physical signs are not helpful and yield no definitive findings.

Table No. 6.

NO.OF OPERATIONS.	INCIDENCE OF ATELECTASIS		ATELECTASIS %.	
	TOTAL	LOBAR	TOTAL	LOBAR
105	9	46*	8.5	43.8*

* See preceding paragraph.

b) Total Atelectasis.

Three of the patients who developed massive lung collapse post-operatively have already been briefly mentioned in the Chapter dealing with the pre-operative preparation for extra-pleural pneumothorax. Each of them, at the time of operation, had a deep selective pneumoperitoneum directed towards the side requiring surgery. The sandwiching effect of the extra-pleural collapse above and the pneumo-peritoneum pushing from below, no doubt reduced the bronchial calibre. Sputum, endobronchial tuberculosis and bronchial spasm were probably the other contributing factors. A further five patients had atelectasis of the entire lung after considerable haemorrhage into the space and some showed massive clotting. Some of these patients too, sustained a tear of the parietal pleura and the additive mechanical effects of: a) a large extra-pleural

effusion, b) a deep intra-pleural pneumothorax and c) an intra-pleural collection of blood, were no doubt precipitating causes. The last patient had an extra-pleural pneumothorax performed for a 'tension' cavity in her left upper lobe. An accidental tear of the pleura occurred and a combined space resulted. The probable factors in the subsequent atelectasis were endobronchial tuberculosis evidenced by the tension-type cavity and the accentuation of the resultant bronchial narrowing produced mechanically by the combined pneumothorax.

In all of these patients the upset produced by the atelectasis was minimal. There was no undue upset of temperature and later exacerbation of pulmonary disease. In every instance the collapse was rapidly reversible and complete re-aeration was achieved within seven to 21 days without any lasting ill effect.

c) Lobar Atelectasis.

Compression atelectasis of the diseased upper lobe was a frequent but bland occurrence in our patients. Approximately 46 (43.8 per cent) showed the typical radiological appearances and were none the worse for it. It must be stressed here that this active compression collapse of the extra-pleural pneumothorax differs radically from the 'relaxation' atelectasis of intra-pleural pneumothorax or pneumoperitoneum. It carries none of the dire pleural and pulmonary sequelae of atelectasis occurring during the course of the two latter procedures. Without exception it has no deleterious effect

on the patient or his disease and interferes in no way with the safe maintenance of the extra-pleural pocket. It ranks more as an interesting, radiological finding, than as a complication per se. In an appreciable number of these patients slow re-aeration of the upper lobe is achieved during the post-operative period but some show persistent 'blacking-out' of the lobe for long periods without any untoward result. By comparison, atelectasis complicating thoracoplasty is a much more grave occurrence. Thomas and Cleland (1942) report that "approximately 20 per cent of all cases" of thoracoplasty sustain a post-operative collapse and comment that "lobar atelectasis is less frequent than total". An incidence of 21.14 per cent in a total of 175 cases is reported by Grigor (1951) from the Mearnskirk Hospital series. He also comments on the preponderance of the massive type and describes the baneful influence of atelectasis on the post-operative course and its contribution to a fatal outcome in three of the cases under review.

d) Endobronchial Tuberculosis and Atelectasis.

In an effort to correlate endobronchial disease with post-operative atelectasis, bronchoscopy was carried out during the induction of anaesthesia in 15 of our patients. Three of them showed general congestive changes without any evidence of stenosis or ulceration in the appropriate main bronchus. None of the 15 developed massive post-operative

atelectasis and thus no helpful evidence to implicate endobronchial tuberculosis as a contributor towards atelectasis was forthcoming.

3. Post-operative Shock.

As noted in the description of the post-operative management of the patient, traumatic shock is conspicuous by its absence. This fairly accurately represents the consensus of opinion recorded in the literature.

4. Subcutaneous Emphysema.

Post-operative emphysema after the standard extra-pleural pneumothorax operation is mainly a radiological phenomenon. A certain minimal amount of emphysema around the wound is inevitable but rarely causes much pain and never becomes obtrusive. This appears to have been the usual experience of most authors on the subject. The only instance of widespread tracking of air in this series occurred in the one patient who had a 'combined' operation. The leakage of air continued steadily for several days, gaining recurrent impetus from the frequent refills administered in an effort to retain the space. Eventually with sealing of the wound towards the end of the first week, the leak ceased and the gross emphysema gradually absorbed.

5. Staphylococcal Empyema.

There have been two instances (1.9 per cent) of staphylococcal empyema of the space in this series and both

were probably avoidable. Neither of them were adequately controlled by topical and systemic penicillin and both spaces were ultimately surgically drained. The accounts of both patients are, the writer thinks, worth recording, even if only to show that with a developed empyema in the extra-pleural space, the modern antibiotics are not the complete answer.

Clinical Case History: (1) Case No.44.

This patient, an adult male of 23 years, had a right extra-pleural pneumothorax performed on 31st August, 1950. The post-operative course was complicated by the occurrence of massive clotting of the blood effused into the space and, as was the custom at the time, operative removal under general anaesthetic was undertaken on 16th September, 1950. At the time of this second intervention, it was observed while re-opening the initial wound that a small, incompletely healed portion, about a centimetre in length, was present in its lower third. It is believed that this small raw area was the source of the organisms which produced the subsequent space infection. The usual dark clot was removed and the wound re-closed. For the first 48 hours the patient remained fairly well but thereafter his temperature rose and alternated between 101 and 103 degrees Fahrenheit. He was lethargic, sweated profusely and complained of severe chest pain. Aspiration of his space on the fourth day yielded thick, yellow pus from which a staphylococcus aureus, insensitive to both penicillin

and streptomycin was isolated. Aureomycin 500 milligrammes, six hourly, was administered for seven days with little result. Both symptoms and temperature were brought gradually under control by repeated aspirations. It was obvious, however, that permanent disinfection of the space was unlikely and accordingly on 18th October, 1950 dependent drainage was procured by rib resection. Thereafter improvement was steady, and complete re-expansion of the lung was achieved. The original cavity was ultimately closed by phrenic crush, pneumoperitoneum and a prolonged period of bed-rest.

(2) Case No.62.

The patient, an adult male of 37 years, suffered from disease affecting the upper thirds of both lungs with multiple cavitation in the right apex and a solitary recent excavation in the left second interspace. His tuberculous infection was complicated by chronic bronchitis. On 4th January, 1951 a right extra-pleural pneumothorax was instituted. After operation his respirations were noisy and numerous moist physical signs were audible in both lung fields. His temperature fluctuated between 98 and 100 degrees Fahrenheit. The early pyrexia was initially attributed to an exacerbation of his bronchitic condition. A satisfactory extra-pleural space existed and was aspirated on two occasions in the first week with the production of a uninfected sero-sanguineous fluid. Examination of the wound on 11th January, 1951 showed an intensive cellulitic reaction. The stitches were removed

and the wound gaped open down to the trapezius muscle. A test aspiration of the space contents on the same day again yielded an uncontaminated fluid. The swinging pyrexia persisted despite intensive systemic and topical penicillin therapy, although some local improvement occurred in the wound. On 22nd January, 1951 however, thin, light brownish pus was aspirated from the extra-pleural space and a staphylococcus aureus sensitive to both penicillin and streptomycin was isolated. A combined attack, using both those drugs reinforced by chloromycetin, given orally in the dosage of one gramme, thrice daily, produced no obvious benefit and eventually late in January, 1951 dependent surgical drainage of the space was carried out. Progress thereafter was uneventful and complete re-expansion of the lung and healing of the wound resulted. The tuberculous process was unaffected throughout and has continued an active course ever since, despite phrenic crush, pneumoperitoneum and routine sanatorium measures.

The cause of this virulent wound infection was traced shortly afterwards to infected silk suture material from which a staphylococcus aureus was also cultured.

Both these empyemata, therefore, were avoidable and in a further 85 extra-pleural operations performed between April and October 1951, there have been no further instances of pyogenic infection of the space. The conclusion reached from these events is that penicillin and the newer antibiotics aureomycin and chloromycetin, are much more efficacious in

preventing space complications than in effectively sterilising an established infection.

With the powerful addition of penicillin as a protective, operative umbrella, there has been, as can readily be imagined, a dramatic fall in the incidence of pyogenic space infections in this series as compared with those recorded in the pre-antibiotic era. Dolley and his colleagues (1940) in their very authoritative contribution state that - "This complication has been largely responsible for the widespread adverse reports relating to the procedure." The Table set out below records briefly the empyema rate encountered in a selection of those earlier reports.

TABLE NO. 7.

AUTHOR (DATE)	NUMBER OF EMPYEMATA.	TOTAL NUMBER OF OPERATIONS.	COMMENTS.
Simmonds (1942)	9 (18.7%)	48	Referred to as 'purulent' fluids.
Reid (1946)	4 (7.4%)	54	Includes two B coli infections.
Barret et al (1946)	3 (7.9%)	38	Controlled by pencillin
Arnold et al (1946)	9 (8.1%)	110	Treated by aspiration and sulphonamides.
Stoyko (1946)	30 (20.0%)	150	"These figures correspond to those of other authors"
Smart et al (1948)	8 (15.4%)	52	All pre-antibiotic
Roberts (1948)	14 (14.0%)	100	All pre-antibiotic
Head et al (1948)	9 (10.5%)	86	Up to 1945.
Murstad (1951)	29 (5.0%)	600	All pre-antibiotic.
Cutler (1951)	6 (4.6%)	129	All pre-antibiotic.
Mearnskirk Series (1951)	2 (1.9%)	105	Post-antibiotic.

Although all these reports have appeared during the last ten years, they deal with patients operated on before the introduction of penicillin and apart from Barret's series there is no mention of the routine employment of the drug as operative cover. None of Murstad's cases had penicillin but he records that a further 162 operations have been performed in the past two years without a single space infection. He thinks that this improvement may be due to penicillin. Cutler's six cases all occurred before the antibiotics were available. In three of them loss of space resulted and in the other three the empyema contributed to a fatal outcome. He comments on the later satisfactory results with penicillin and streptomycin which have entirely eliminated secondary infection of the extra-pleural space.

The pre-1940 literature is to a large extent somewhat vague as to the frequency of extra-pleural empyema. Maurer (1938), Brock (1938), Sellors (1938) and Rhodes (1937) all mention the complication but provide no figures for the series they report. Maurer states - "Fortunately it is not very alarming....." while Brock remarks that it is "inevitable at times" just as in artificial pneumothorax. Rhodes is of the opinion that "infection of the cavity is very rarely encountered but it is a possibility....."

To summarize, therefore, pyogenic infection with modern drug cover is extremely rare and but for accidents, such as those described, is almost entirely avoidable. When purulent

involvement of the space becomes established, antibiotic treatment alone is not completely efficacious and surgical drainage of the space may be necessary. The great value therefore of penicillin and streptomycin lies in their preventive capabilities.

6. Bronchogenic Spread of Disease.

Each of the patients in this series has been carefully followed up during the post-operative phase by frequent x-ray and clinical examination and in no case has there been any evidence of exacerbation or spread of tuberculous disease. This again compares favourably with most of the earlier writings and the credit is due entirely to the intensive routine use of streptomycin and para-aminosalicylic acid. The The previous magnitude of the problem of post-operative spread of disease is reflected in Roberts meticulous follow up of 128 patients operated on in the Brompton Hospital between 1937 and 1942. The 14 late deaths in the 100 patients submitted to the standard operation were due to relentless onward progress of disease in spite of the operation. The removal of this disastrous aftermath has eliminated effectively the second of the sequelae which brought this method of treatment into disrepute in the late nineteen thirties.

C. Complications Occurring Late in the Post-operative Course.

1. Late Transient Effusion.

A simple, serous, transient effusion occurred several

months after operation in two of our patients. There was no systemic upset whatsoever and the patients were completely unaware of the existence of the fluid which was detected at routine ante-refill fluoroscopy. The first one, occurring six months after operation, disappeared after two aspirations and the second, appearing after nine months, cleared spontaneously. The fluid aspirated from the former patient was negative for tubercle bacilli by direct examination, concentration and culture methods. There has been no recurrence in either case and both spaces are still excellently maintained by air refills.

2. Late Persistent Effusion.

A persistent, un-infected effusion occurred on four occasions. Again the tubercle bacillus was undetectable, but in each instance the effusion was accompanied by progressive dwindling of the extra-pleural pocket. Three of these patients produced the fluid within the first two post-operative months after the surgical removal of massive space clot. Indeed, complete drying of the space, after the second intervention, was never achieved and in each case a steady thickening of the space walls became obvious. The fluid withdrawn had a thin sero-sanguineous character. To prevent complete space loss, a thoracoplasty was performed on two of the patients, and in the third olive oil was used to convert the space to an oleothorax.

In the fourth and final patient a persistent uninfected effusion appeared 15 months after operation. Satisfactory evacuation of the space was rendered difficult by reason of a severe ankylosing spondylitis. The chest wall, particularly posteriorly, had a consistency of leather and alteration of needle position was practically impossible. The fluid maintained the space in diminishing degree without refill for several months but has now practically absorbed. The lung is almost completely re-expanded and the disease appears satisfactory.

3. Air Embolism.

Although on several occasions, particularly in initially shallow spaces, air refills have been administered into the lung, no air emboli have resulted from this form of accident. On one occasion the major cavity undergoing compression was aspirated without ill effects.

One very interesting, dangerous and hitherto undescribed form of air embolism has however been encountered on four occasions - twice in the same patient. The embolic manifestations in each case have been very brief and there has been no fatality. The four incidents have all followed an identical pattern. The actual refill is carried out uneventfully. Normal pressures are recorded and the usual quantity of air administered. High terminal pressures are, of course, left in the space. The patient rises from the table feeling perfectly well and the embolic symptoms only

become manifest five to 30 minutes later. It is believed that air gains access to the circulation by leaking from the space along the needle track and thence into a small vessel lacerated during the introduction of the refill needle. The high space pressures naturally contribute to this occurrence and the most surprising feature is that such an accident does not occur more frequently. The symptoms are the usual ones - dizziness, diplopia, paraesthesiae, etc. Loss of consciousness, convulsions, relaxation of sphincters, etc. have not occurred. Persistent severe headache is a frequent later result. The phenomenon has been named 'rebound air embolism'.

Such an occurrence, potentially dangerous at all times, is particularly menacing in the case of out-patients. One of our patients developed his symptoms while returning to town by bus. The journey, fortunately, occupies some 30 minutes and by the time he had reached town he had partially recovered. Another male patient, with bilateral extra-pleural pneumothoraces, who has suffered two embolic accidents, persists in driving himself to the hospital for refills despite dire and pointed warnings. If no gradual percolation of sense occurs, conversion to oleothorax will be considered.

A strikingly similar sequence of events is described by Proctor (1940) but is attributed by him to "reaction to high pressure". It will be remembered from the section describing post-operative management that he works on the principle that it is "necessary to use progressively higher

pressures to put in the same amount of air from time to time." His end pressures have reached the phenomenal level of 130 centimetres of water. With such readings he describes "alarming cerebral symptoms" which can be relieved by the removal of some air. The symptoms are suspiciously like those of air embolism but he postulates "mediastinal compression" as the cause. The relief afforded by the removal of air could fit in with an embolic theory when it is considered that the pressure maintaining the leak into the circulation is immediately removed by this manoeuvre.

4. Tuberculous Empyema.

A tuberculous infection of the extra-pleural space has occurred on three (2.8 per cent) occasions and the main impression formed regarding this apparently serious complication has been one of surprise at the benign course it follows. The patients concerned have pursued a path of apparently unaltered general health despite regular aspirations of pus from the pneumothorax. Smart et al (1948) also comment on the mild systemic upset associated with extra-pleural empyema as compared with the intra-pleural variety. They attribute this to the relative impermeability of the membranous lining of the extra-pleural space. The maintenance of general well-being and even working capacity, in the face of the tuberculous infection, is also remarked upon by Cutler (1951) and Proctor (1940).

The source of the space infection is a matter for some conjecture and it is impossible from the limited numbers in this series to draw any hard and fast conclusions. There does not appear to be, however, a connection between the initial extent of the tuberculous involvement of the lung and subsequent tuberculosis of the space. Of 11 cases in this series, which could be grouped under the 'conditional' classification of Dolley et al (1940), indicating very advanced disease, only one later developed a tuberculous empyema. Cutler echoes these remarks in his series.

The initial difficulty of the extra-pleural strip is suggested as a factor by Barret et al quoted by Reid (1946). They cite the following figures in support of their contention. After 31 easy pneumonolyses, 16 per cent of the patients developed a tuberculous infection of the space. In seven difficult operations, 70 per cent were complicated by space tuberculosis. In two of our empyema cases mobilisation was difficult and in one was left incomplete, but no definite conclusion can be drawn from such small numbers.

Several workers comment on the dangers of stripping the lung with the large apical, so-called 'subpleural' cavity. They speak of depriving the lateral wall of the cavity of its blood supply by performing a pneumonolysis in those circumstances, thus paving the way for later sloughing with the production of a caverno-extrapleural fistula and tuberculous empyema - a dire combination. This is

theoretically a strong argument and although several large, subpleural cavities have been treated by extra-pleural pneumothorax among our cases with frequently gratifying result, it must be mentioned that one went on to later tuberculous empyema without obvious fistula and one developed an overt broncho-extra-pleural communication. The assessment, however, of the 'sub-pleural' cavity requires some further description. Usually a cavity is diagnosed as being sub-pleural in position on the strength of the ordinary postero-anterior skiagram. If it is obviously so in this film, it is in order to give it the name sub-pleural. Many cavities, however, require lateral radiography for an adequate assessment of their site. A cavity may abut on the pleura in the paravertebral gutter or on the mediastinal surface of the lung and yet appear to have a mantle of lung tissue surrounding it in a postero-anterior x-ray. Indeed, it is difficult to picture a cavity of any size in the upper lobe which does not approach the pleura in one of its aspects. The term, sub-pleural cavity, therefore actually embraces a majority of upper lobe cavities and is still used somewhat loosely. Le Foyer et al (1948) actually devote a short article to the praises of extra-pleural pneumothorax in the treatment of voluminous apical cavities and describe an instance in a young woman successfully treated in this manner. They make the very good point that these cavities are not amenable to other forms of surgical treatment and point out

that even an extensive thoracoplasty may leave a slit gutter cavity.

Cutler states with certainty that the cause of extra-pleural infection is the direct result of the rupture of the contents of subpleural tubercles into the space in much the same way as in intra-pleural pneumothorax. This would appear to be the most glib explanation in the absence of a definite broncho-extrapleural fistula.

The course of the infection in our three patients was briefly as follows:-

Abbreviated Case Reports:

Case 2. A female, of 18 years, developed a persistent, initially clear effusion, six months after operation. The fluid gradually changed to a brownish-yellow pus over the course of a few weeks. The tubercle bacillus was recovered by guinea-pig inoculation. Refills were abandoned and regular aspirations with the insertion of one gramme streptomycin and 10 millilitres of a 20 per cent solution of P.A.S. were carried out. The lung slowly re-expanded and the incompletely stable disease was ultimately controlled by phrenic crush and pneumoperitoneum in April 1951. This management of the case was effected at out-patient visits apart from a brief 14 days period in hospital for phrenic crush and pneumoperitoneum induction.

Case 79. A male of 41 years showed a persistent effusion after his operation for clot removal. A slow transition

to pus followed and a localized breakdown of his wound occurred giving a temporary extra-pleural-cutaneous fistula which closed with ultimate lung re-expansion. Examination of the pus by smear, concentration and culture, failed to produce the tubercle bacillus, so the diagnosis of tuberculous empyema is presumptive only. He still requires aspiration of a limited apical space and thoracoplasty is being considered, although his underlying disease has been considerably improved.

Case 91. A girl of 16 years with advanced tuberculous involvement of her right lung and resolving infiltration in her left upper third. The right upper lobe was almost totally excavated and in addition a large right dorsal lobe cavity was present. A right extra-pleural pneumothorax was performed on 21st March, 1951. A small effusion persisted post-operatively and after five months changed to pus which again has failed to yield the tubercle bacillus by smear, concentration and culture. Diagnosis, again, therefore is presumptive. The space has been so far maintained with sporadic aspirations and regular insertion of streptomycin and P.A.S. In October, 1951 when she reported for out-patient assessment the girl was very well and the B.S.R. had dropped from 91 millimetres in the first hour (West.). to 23 millimetres in the first hour. The upper lobe cavity had disappeared and the dorsal lobe cavity, though perhaps not entirely closed, was considerably reduced in size. Her future management has not yet been decided.

This minor incidence rate of 2.8 per cent without calamitous sequelae compares favourably again with the pre-streptomycin figures of which the following selection is fairly typical.

TABLE NO.8.

AUTHOR (DATE)	NUMBER OF TUBERCULOUS EMPYEMAS.	DEATHS.
Thompson & James (1942)	8 (26.6%)	Not stated.
Russo (1943)	8 (21.2%)	Not stated.
Reid (1946)	11 (20.4%)	Three.
Alley (1946)	7 (13.7%)	Not stated.
Roberts (1948)	13 (13.0%)	Six: post-operative One: late.
Murstad (1951)	73 (12.0%)	Twelve. (Ten of bronchial or oesophageal fistulae).
Cutler (1951)	27 (29.6%)	Nil.

The reasons for the wide variation between 12 and 29.6 per cent are probably to be found in the differing standards of those authorities as to what justifies the name of tuberculous empyema. Murstad, for example, does not include in his figures the many patients who have a scanty, cloudy fluid, yielding the tubercle bacillus on culture. Such effusions he observes may persist for a long time without

impairment of general health and may disappear spontaneously. Cutler, with his 29.6 per cent, includes such patients.

Despite this it is obvious that tuberculous empyema was formerly a common if not always a grave occurrence and even a conservative estimate of frequency would place it in excess of 10 per cent. Indeed Cutler's standard of an effusion producing tubercle bacilli is technically the most accurate one and places the figure nearer 30 per cent. By comparison 2.8 per cent (two of them bacteriologically unproven) testifies to the efficiency of streptomycin as a powerful preventive drug and a further means of removing another deterrent from the large scale performance of extra-pleural pneumonolysis. Even should empyema occur, it is still compatible with maintenance of good general health and appears to be controllable fairly readily.

5. Broncho-extrapleural Fistula.

This is a dire but fortunately rare complication. It has only appeared once in this series (0.9 per cent). The patient, Case 45, a woman of 29 years, had a left extra-pleural pneumothorax performed on 28th September, 1950 for a fairly thick-walled six centimetre sub-pleural cavity in her left upper lobe. Her post-operative course was complicated by massive clotting and at the time of clot removal a small area of the apice-lateral aspect of the lung was seen to have no covering of organising blood-clot. The significance of this was not realised and the space was maintained with

initial satisfactory results as far as cavity closure was concerned. Six weeks after the original operation she was discharged to another hospital and was only referred back to us some thirteen months later. It had been noted that refills produced no rise in space pressure. A diminished extra-pleural space persisted with the cavity on a somewhat reduced scale, re-opened below. There was no effusion but a test refill produced no pressure rise. A formal thoracoplasty in the Overholt position was then embarked upon and two stages have been performed to date. Confirmation of the fistula was afforded after the first stage by almost complete loss of effective coughing and by a scattered non-specific, patchy consolidation of the contralateral lung. She appears to be weathering this storm successfully at the present time but the ultimate outcome remains uncertain.

Murstad (1951) encountered 28 (4.7 per cent) cases of broncho-extrapleural fistula in his 600 patients. Three appeared within two months and 13 had developed within four months. Of the 15 late cases, 11 had had a tuberculous empyema for weeks or months before showing signs of fistula. Out of six necroscopies he found an identical picture in four patients. The lateral wall of the cavity was almost entirely destroyed and the rest of the cavity formed a shallow, ulcerated crater with the drainage bronchus in the floor. He advocates the exclusion of patients with large superficial cavities. Other workers tell of similar results and the

gravity of the condition is obvious. Seip (1950), for example, with his large series of 539 cases, finds that a patient developing a broncho-extra-pleural fistula usually dies. He goes on, however, to state that such deaths are not frequent enough to interfere with successes and are easily counterbalanced by the more common bugbear of the post-thoracoplasty, residual cavity. Roberts (1948) records seven (7 per cent) and three of them subsequently died. The usual form of treatment reported for the established fistula is thoracoplasty,but lung resection with modern technique is now a possibility.

Although we have been impressed by the gravity of the complication in this one instance in our cases, we are equally impressed by the rarity of its occurrence. Even allowing for difference in operative technique, selection of case, etc. there is still a considerable margin of difference between 0.9 per cent and such figures as the seven per cent mentioned above. Once again the main variable factor is streptomycin, although it can hardly take credit for preventing mechanical rupture of a cavity. It can, however, be of considerable assistance in controlling and preventing the further eroding progress of a lesion and by so doing may contribute towards the prevention of the disaster. The probable method of production of the fistula in our one patient seems to hinge round the inability of the extra-pleural collapse to achieve closure of the very

large cavity. Perusal of the x-rays show that although dramatic reduction in cavity size occurred after operation, complete closure was never obtained. Probably the start of the trouble can be traced to the first three post-operative weeks when clotting of the space blood prevented pressure refills. The erosion noted at clot removal has been mentioned. If those large cavities are not rapidly and completely closed by extra-pleural pneumothorax, sloughing of the outer cavity wall is a distinct danger. Thoracoplasty should be resorted to at an early date and has a greater chance of success after the pneumothorax has reduced the cavitary size and displaced it to a situation more amenable to thoracoplastic compression.

6. Other Fistulous Combinations.

Other fistulous combinations e.g. oesophago-extrapleural: broncho-extrapleural-cutaneous, etc. etc., have not occurred in our cases. These again are disastrous complications and have been sporadically recorded in the literature. Bérard et al (1948b) reports three cases of the oesophageal variety after tuberculous empyema and postulates a lymphatic pathology. He recommends gastrostomy followed by thoracoplasty as a possibly successful mode of treatment.

Such fistulae are reported more as rarities rather than as expected post-operative complications and no comparison with other figures is possible. Many authors, indeed, make no reference to them at all.

CHAPTER FIVE.

RESULTS.

1. VITAL STATISTICS.

In all, 105 operations were performed on the 100 patients under review. The 'standard' procedure was employed on 104 occasions and there was one semi-accidental 'combined' operation. (See Chapter Three). In five patients, both lungs were surgically collapsed and in a further three, active disease in the contra-lateral lung was controlled by artificial intra-pleural pneumothorax. Of the remaining 95 with unilateral extra-pleural collapse, the right lung required operation on 50 occasions and the left, on forty-five. Fifty four of the patients were males and 46, females. The age distribution of the patients and their duration of disease have already been referred to in Chapters Two and Three. It may, however, be recorded once more that the ages ranged from 11 years to 55 years, 27 patients were under 20 years of age, and the majority of the cases - 40 (40 per cent) were drawn from the 20-29 years group. The average disease duration was found to be two years and nine months, with extremes of 11 years at the upper end of the scale and five months at the lower.

2. FOLLOW-UP.

A. Duration.

The first extra-pleural pneumonolysis was performed on

February 2nd, 1950 and our hundredth patient had his operation on April 12th, 1951. Every patient was finally reviewed in October, 1951, giving a longest follow-up period of 20 months and a shortest one of six months. Over the 100 cases the average period of observation was one year. Details of the length of follow-up are recorded in Table No.

TABLE NO. 9.

Duration of Follow-up in 3 month Groups.					Total.
18-20	15-17	12-14	9-11	6-8	
9	33	7	20	31	100

The small number of patients operated on in the first three months after the re-introduction of extra-pleural pneumothorax is shown in the 18 to 20 month follow-up group. During those early experimental months the tempo was necessarily slow, but with increasing evidence of good early results, impetus was rapidly gained and 33 operations were performed in the three months that followed. A rapid drop to seven operations occurred in the next quarter. This period coincided with the holiday season for the senior surgical members of the team and at this time operations of election, such as extra-pleural pneumothorax, were considerably reduced. A steady turnover was resumed for the last six months of the period. It can also be seen

from the Table that 49 patients have now been assessed for periods in excess of one year.

B. Methods and Standards of Follow-Up.

As many as possible of the patients undergoing this operation are maintained as out-patients at Mearnskirk Hospital for the purposes of refills and observation. Thus 61 (61 per cent) of our cases have remained in our hands, either as in-patients or on a regular out-patient basis. The remaining 39 were returned to their parent hospitals after operation, and after final dismissal were either retained there or referred to the local chest clinic of the districts in which they resided. For the purposes of review in October, 1951, each patient was requested to attend Mearnskirk Hospital and 94 contrived to appear. Of the other six, one patient was in a Swiss sanatorium and was seen by Mr. Barclay there while he was visiting Continental clinics, two lived in Dumfries and three were Glasgow patients who found it impossible to attend because of regular employment. The details of the Dumfriesshire patients were kindly supplied by Dr. C. Clayson, Area Supervising Tuberculosis Physician and the Glasgow absentees were re-assessed by Dr. N. McSwan of Ruchill Hospital. Full follow-ups, therefore, were obtained on each of the 100 cases involved. Uniform standards were adopted throughout by recording all the relevant data on each case on a standardized typewritten form. The 94 patients reporting

at Mearnskirk were reviewed by the writer in the company of Mr. R. S. Barclay, Consultant Thoracic Surgeon to the unit.

This late examination included an assessment of general condition, clinical examination of the chest, enquiry as to any possible symptoms, bacteriological investigation of the sputum, chest radiography and estimations of vital capacity, B.S.R. and weight. The sputum was considered negative if three consecutive specimens and a final laryngeal swab, examined by direct smear, concentration and culture, failed to reveal the tubercle bacillus. No guinea-pig innoculation was carried out for two main reasons. The first, a materialistic one, was because the guinea-pig population of the hospital was insufficient to cope with such a volume of patients negative by ordinary standards. The second concerns the management of the tuberculous patient as a whole. It was felt that the soul-less pursuit of the sporadic and elusive bacillus by such sensitive means did not afford help in the practical management of the patient. If active tuberculosis has been effectively treated by clinical, radiological, serological and routine bacteriological standards, it rarely helps either doctor or patient if a stray tubercle bacillus is demonstrated by such a sensitive test as guinea-pig innoculation. The same point is made by Head et al (1948) who do not advise gastric lavage and guinea-pig innoculation in patients undergoing surgical treatment.

They are of the opinion that these tests are too delicate for clinical handling and that a positive result only confuses and worries the patient and does not alter the clinical management. Despite these remarks, however, it is essential to have adequate sputum investigation along the lines described above, i.e. three direct smears, concentration and cultures, and if negative, laryngeal swabbing. It is useless to rely on direct smears of the sputum or to depend for that matter on the average female patient producing a satisfactory specimen for investigation. Yet all too frequently in the literature, no mention is made of bacteriological standards when referring to sputum conversion. The remarks by such an authority as Morriston Davies in his provocative talk on pulmonary tuberculosis (1948) are worthy of repetition. He writes - "Is it not time we became more precise as to when a patient is a tuberculous positive or negative case? I admit that when a sputum positive case has had an operation and three successive smears are negative, it is very comforting to one's self respect. How disturbing then to one's attempts at self deception when some enquiring busybody produces a positive result from a laryngeal swab or a gastric lavage or, later reports that the culture was positive. I am glad to note that we are recently becoming more conscious of the need for distrusting, except as a general indication, the findings from direct smears."

On the basis of their condition at the time of follow-up the patients have been subdivided into successful and unsuccessful categories. It is immediately obvious that there are two ways of assessing success in this operation. As the principal object of pneumonolysis is to produce an adequate extra-pleural space which logically must be maintained until healing of the tuberculous process is achieved, success can be measured in terms of persistence or otherwise of the original space. Within the comparatively brief period covered by this survey, the decision to abandon the collapse deliberately in a patient because of obvious disease healing, was never taken. If the space could be maintained, by either air or oil, it was persisted with to give the lung every possible chance of recovering and thus prevent premature re-expansion, with perhaps later exacerbation of disease. A broader conception of success, of course, is based on the therapeutic result, at the time of review, irrespective of space maintenance. A patient, deemed to have a satisfactory outcome by such standards, may have shown progressive inexorable dwindling of the extra-pleural space with ultimate complete re-expansion of the lung. By fortuitous circumstances, the lung may have been compressed long enough for cavity closure and disease healing to be effected.

The former method of assessment has been employed as being probably the more accurate and certainly the more

readily described. The overall picture, based on therapeutic benefit, will be appended later. The final criteria adopted, therefore, in assessing a successful outcome were as follows:-

1. Extra-pleural collapse adequately maintained by either air or oil with complete radiological and clinical control of disease.
2. Satisfactory general condition with absence of any chest symptoms.
3. Sputum repeatedly negative for tubercle bacilli according to the bacteriological standards just described.
4. Satisfactory sedimentation rate and weight readings.

Eighty (80 per cent) of our patients fulfilled these standards. This number includes 76 of the air filled spaces mentioned in Table No. 10. and nine of the 11 oleo-thoraces. The total of 85 extra-pleural spaces is made up by the five bilateral cases. The remaining 20 (20 per cent) comprise the so-called unsuccessful group. They include unsuccessful oil conversions, spaces obliterated by later thoracoplasty and patients in whom abandonment of the space was necessitated by the onset of empyema. It should be remembered that only seven of these patients still have a positive sputum and only one has died.

The ultimate fate of the space in the 100 patients is

shown in Table No. 10 .

TABLE NO. 10.

FATE OF SPACE.	NUMBER.	PER CENT.
Maintained by Air Refills	77	(73.3)
Converted to Oleothorax	11	(10.5)
Converted to Thoracoplasty	8	(7.6)
Voluntarily Abandoned: (a) Staphylococcal Empyema 2. (b) Tuberculous Empyema 3.	5	(4.7)
Involuntarily Abandoned: (a) Persistent Effusion 1. (b) Initially Inadequate Space 1. (c) Inadequate Refills 1.	3	(2.9)
Resection of Lung (Inadequate Disease Control)	1	(1.0)
TOTAL:	105	(100 per cent)

3. ANALYSIS OF SUCCESSFUL AND UNSUCCESSFUL RESULTS.

A. Successful.

Eighty patients (80 per cent) qualify for this group. They include the five with bilateral operations and the number of extra-pleural spaces involved therefore is eighty-five. The division into air and oil maintenance is shown in Table No.11 .

TABLE NO. 11.

METHOD OF SPACE MAINTENANCE.	NUMBER.
Air	76
Oil	9
TOTAL:	85

Despite the good end results in every case, some of these patients had early post-operative complications. No fewer than 15 showed massive clot formation in the space, necessitating later operative removal. Eleven sustained tears of the parietal pleura, some with troublesome resultant combined spaces. One showed a superficial staphylococcus aureus wound infection, which cleared without incident. One man had a massive post-operative haemorrhage which required replacement transfusion and one girl had a late transient sterile effusion which cleared after one aspiration. Several patients showed transitory total atelectasis, but no troublesome space infections occurred. One patient, Case No.70, had a giant emphysematous bulla as a complicating factor at the time of operation. His radiological appearances were spectacular and his post-operative course is worthy of mention.

Clinical Case History. Case No.70.

The patient, a male of 29 years, was admitted to Mearnskirk Hospital in August, 1950. He gave a three and

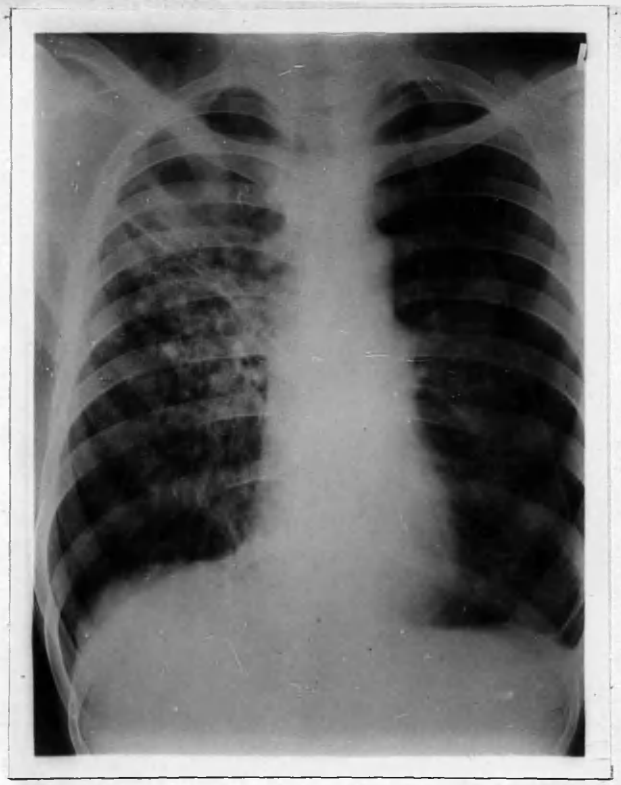


Fig.25.

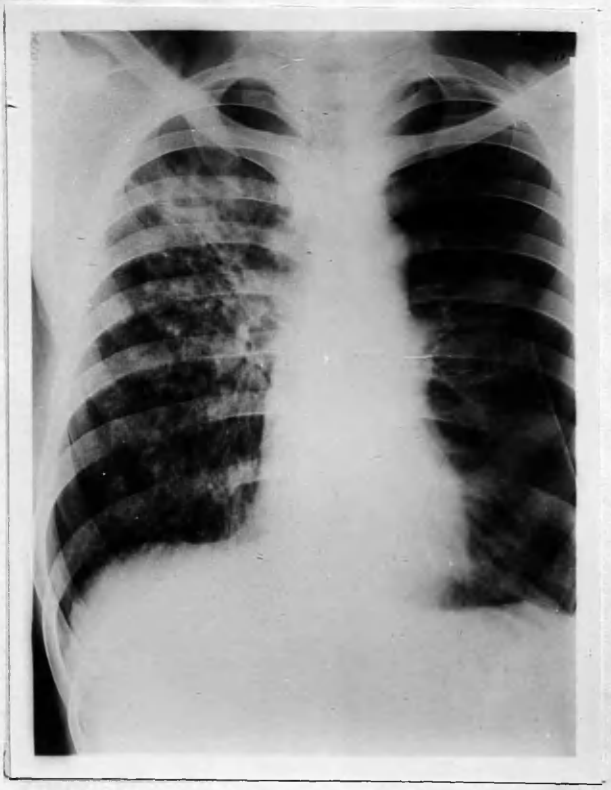


Fig.26.

a half year history of bilateral pulmonary tuberculosis treated by various periods of bed-rest and a left artificial pneumothorax, which had already had two thoracoscopies and partial adhesion sections. At the time of admission he was in poor general condition, his sputum was positive by direct smear and his B.S.R. was 45 millimetres in the first hour (West.). An x-ray of his chest showed extensive caseo-cavernous involement of all zones of his right lung with a peculiarly honeycombed translucent appearance in the upper third. A left artificial pneumothorax, with a single, tenuous, apico-lateral adhesion, was controlling quite effectively some unstable disease in the left upper lobe. The appearance in the upper zone of the right lung was not accurately construed and was even thought, initially, to be due to tuberculous excavation with a certain amount of overlying pleural thickening. Fig.25. shows the radiological appearance on admission.

A regime of bed-rest and oral P.A.S. therapy (18 grammes per diem) was commenced and maintained for five months. The adhesion in the left artificial pneumothorax was severed in October, 1950. By January, 1951 considerable clinical and partial radiological improvement had occurred. The peculiar right apical appearances were unchanged, although some reduction in the disease in the right lower half was manifest. The left lung appeared satisfactorily controlled. Fig.26. shows the radiological appearance at this stage. On

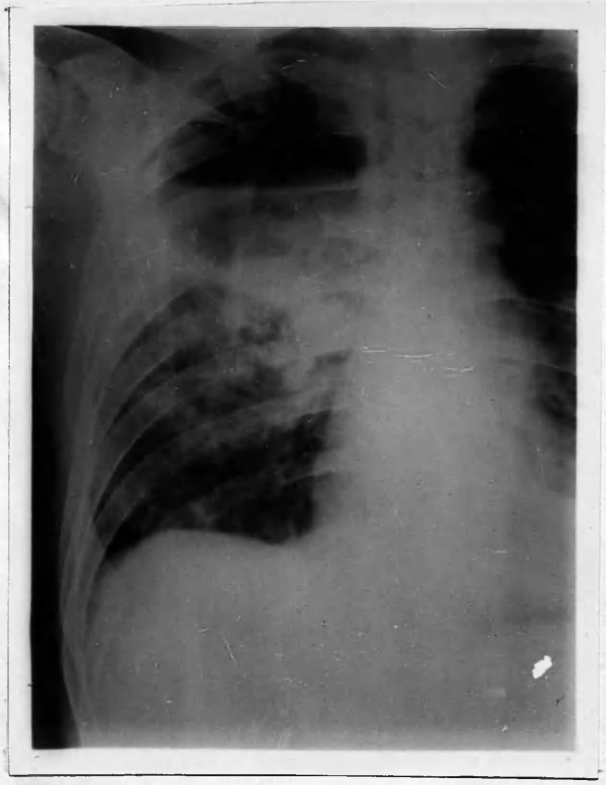


Fig.27.

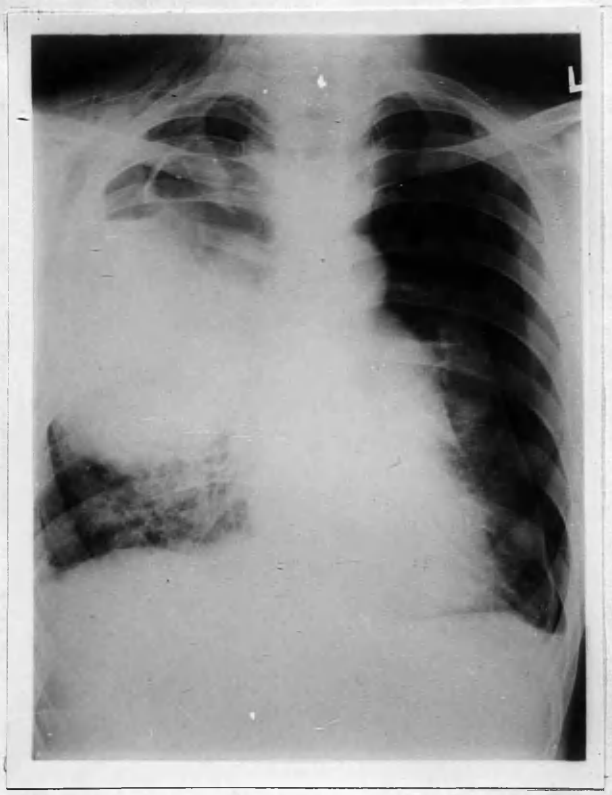


Fig.28.

2nd February, 1951 a right extra-pleural pneumonolysis was commenced. At an early stage of the mobilisation it was realised that the abnormal radiological translucency was due to the presence of a giant emphysematous bulla. It approximated in size to an orange and occupied the site previously taken up by the right upper lobe. The apicolysis was continued uneventfully and a standard strip was finally achieved. The usual closure was effected and the patient returned to the ward. The first post-operative film on 3rd February, 1951 showed an alarming increase in the size of the bulla which almost filled the entire extra-pleural space. Fig. 27 . Only a slender cushion of air separated it all round from the chest wall. At the first attempt at refill the needle was accidentally inserted into the bulla. Pressures of -5 +5 centimetres of water were recorded and 200 cubic centimetres of air administered without any pressure change or ill effect. The needle was then slowly withdrawn and readings of 0 +5 centimetres of water appeared. Three hundred millilitres of air were introduced and the final recording was +10 +15 centimetres. No aspiration was attempted. Fig. 28.shows the x-ray appearances next day. The bulla is slightly smaller and the encircling space is deeper.

Refill was again carried out, this time uneventfully. Further frequent refills eventually stabilised the space and compressed the bulla to the point of extinction. An

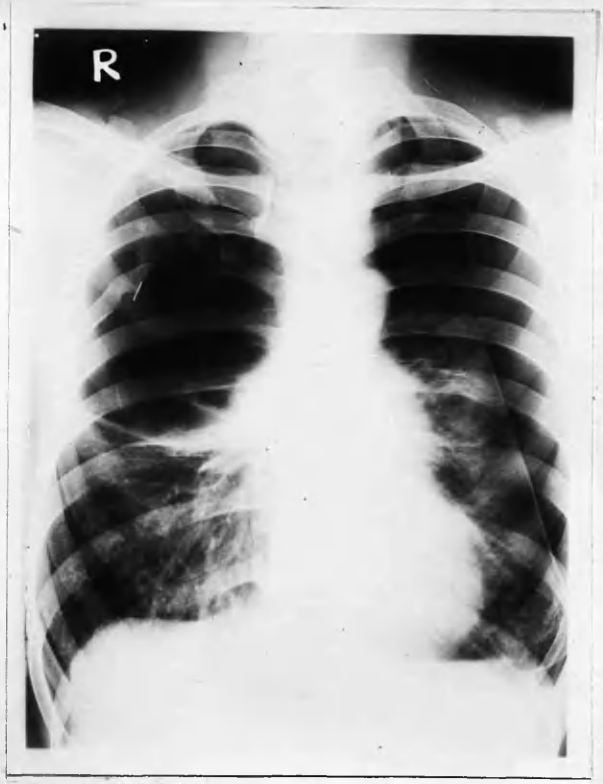


Fig.29.

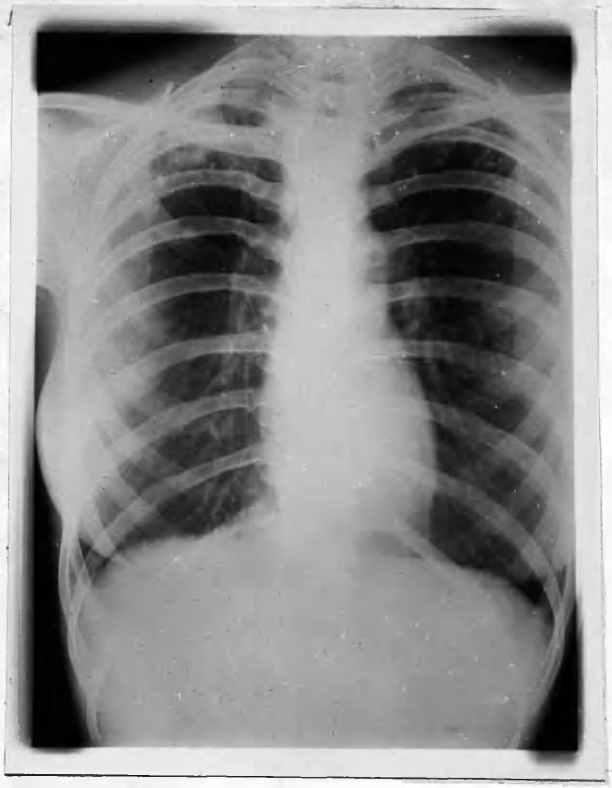


Fig.30.

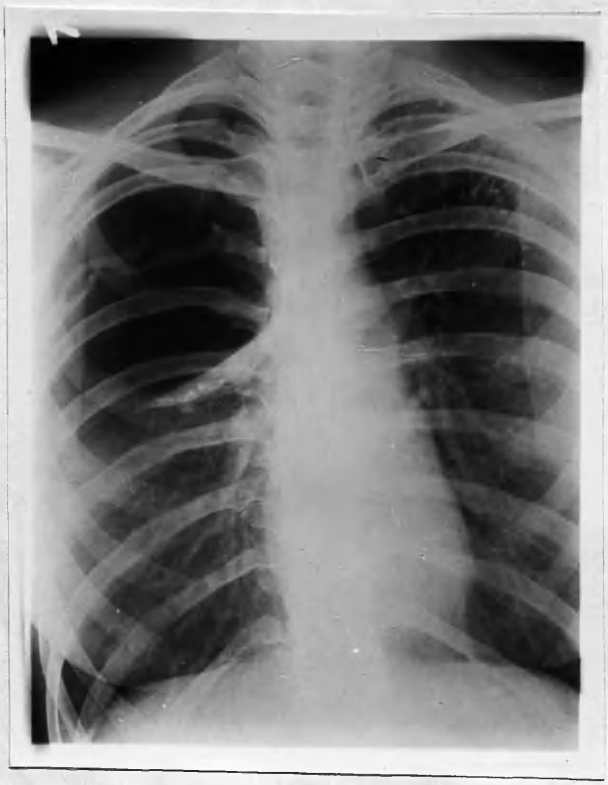


Fig.31.

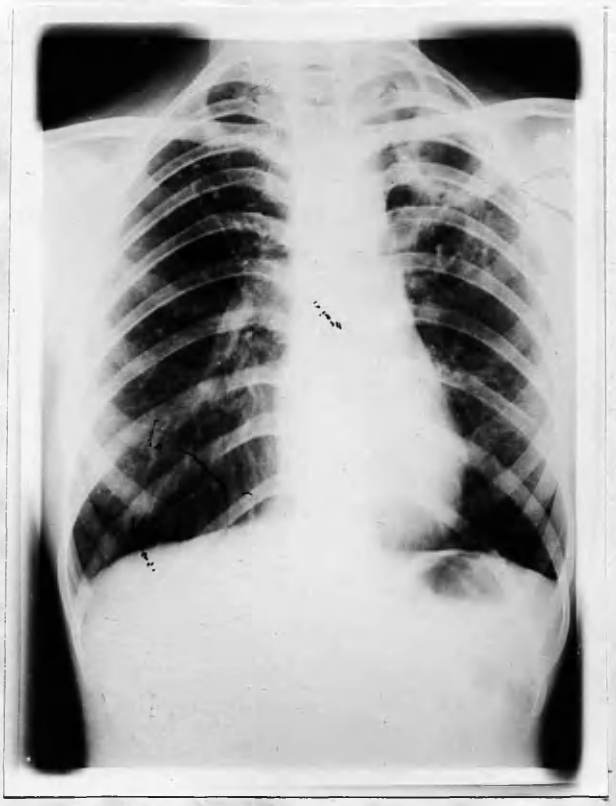


Fig.32.

eminently successful result was the outcome and the final picture recorded at out-patient review in October, 1951 is shown in Fig. 29. His sputum is repeatedly negative and his B.S.R. - 3 millimetres in the first hour (West.).

A selection of some of the pre and post-operative films from patients in this group is shown to illustrate the efficacy of extra-pleural pneumothorax in controlling the active excavated tuberculous lesion.

Brief Illustrative Clinico-radiological Reports.

1. Case No.32.

Female, aged 22. Four years history. Treatment - bed-rest and failed right artificial pneumothorax. B.S.R. 25 millimetres. Fig. 30. pre-operative state. Scattered calcified disease both upper thirds. Thin walled one inch cavity in apex with several smaller surrounding ones. Operation - 29.6.'50. Fig. 31. shows post-operative state as out-patient October 1951 - working as clerkess. Excellent right extra-pleural pneumothorax space. Disease calcified. Left lung satisfactory. Fortnightly refills. B.S.R. - 4 millimetres (1st hour).

2. Case No.68.

Female, aged 20. Three year history. Treatment - bed-rest and oral P.A.S. B.S.R. - 38 millimetres (1st hour). Fig. 32. - pre-operative state. Unstable infiltration right upper quarter without obvious cavitation. Large ovoid cavity, two inches in greatest diameter, occupying major portion of

Fig. 33.

Fig. 34.

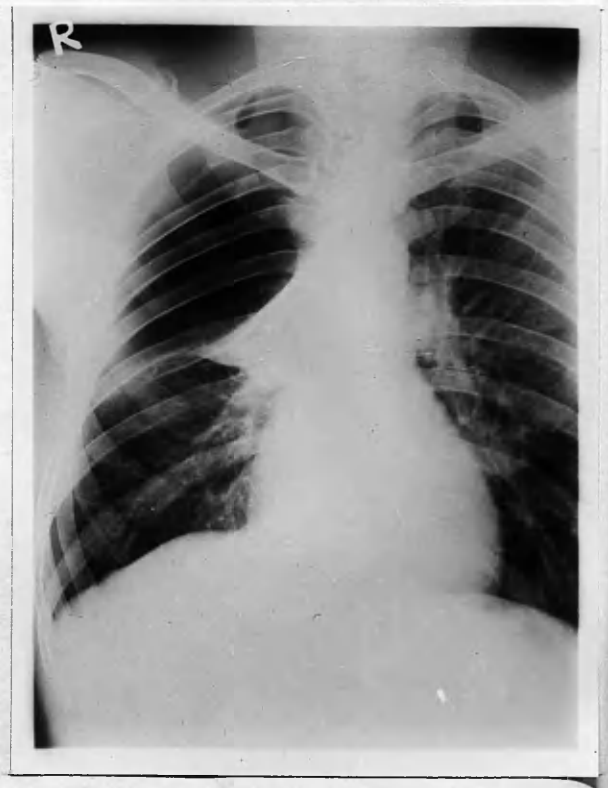


Fig. 35.

left upper lobe - 'Subpleural type'. Some scattered infiltration down to left mid zone.' Operation - 25.1.'51. Fig. 33.post-operative state at time of out-patient review in October, 1951. Right sided infiltration fibrosed. Left extra-pleural space extends to back end of seventh rib. Disease well compressed. No activity or cavity. B.S.R. - 5 millimetres (1st hour). Fit to return to work but has not yet done so. Weekly refills.

3. Case No.90.

Male, aged 34 years. One year history. Previous treatment - bed-rest and unsatisfactory right artificial pneumothorax. B.S.R. - 32 millimetres (1st hour). Fig.34. pre-operative state. Fibro-caseous disease upper half of right lung with cavitation in right second interspace. Root shadow enlarged. Early deposit at lateral end of left first interspace. Operation - 21.3.'51. Fig. 35. post-operative out-patient state at October, 1951. Excellent space with adequate disease compression - no activity or cavity. Left lung clear. B.S.R. - 1 millimetre (1st hour). Returning to work as a college teacher of technical subjects. Refilled every 10 days. This man had the additional interesting experience of flying in an unpressurised aircraft. At 9,000 feet, severe chest pain, dyspnoea and tightness developed and he practically collapsed. Descent to 6,000 feet gave complete relief and apart from exhaustion at the end of the flight he was none the worse of his

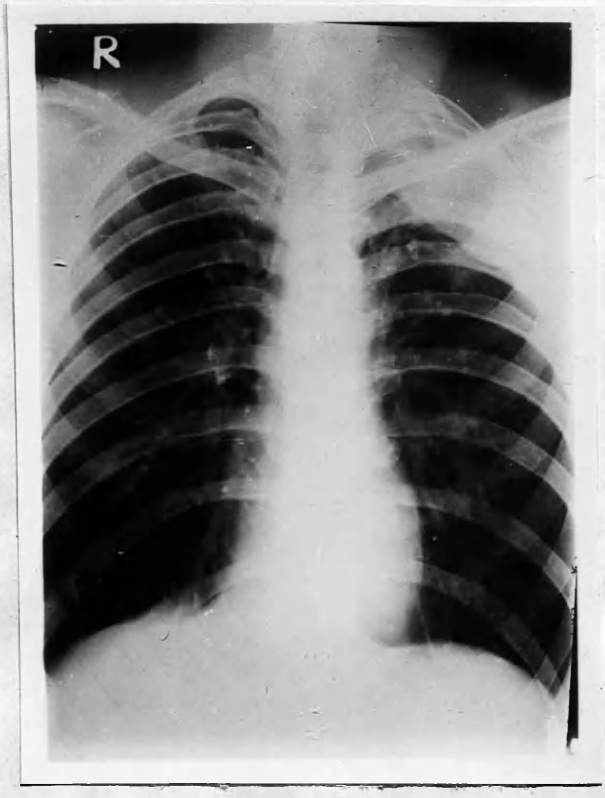


Fig. 36.

experience.

This successful group also includes nine oil filled spaces. Liquid paraffin was employed twice and the remaining seven had olive oil replacement. There have been no disastrous sequelae in any of these patients and several of them are now working full time. Seven spaces were converted to oil because of inexorable dwindling of the pocket and two were carried out for disinfection reasons. The only mild complication occurred in one of the patients who received liquid paraffin. About six weeks after the space had been filled he reported as an out-patient with a fluctuant subcutaneous swelling in the region of his healed operation wound. Presumably the effusion, excited by the presence of the oil, had so increased the space pressure that the oil-effusion emulsion had to find an outlet and the operation wound provided the safety valve. Aspiration of the swelling caused it to subside and there has been no recurrence to date over the period of 14 months. The only late relic of this herniation is a small paraffinoma of the wound which gives no trouble and indeed has never been noticed by the patient who is now employed full time as a bookstall assistant. His latest x-ray, reproduced in Fig. 36 , shows an apical oleothorax extending to the back end of the fifth rib. The underlying disease is partially calcified. This patient's extra-pleural pneumothorax was performed on 10.5.'50 and oil

replacement was carried out three months later.

B. Unsuccessful.

This is a heterogeneous group which embraces all those patients who, by reason of abandonment of their extra-pleural space or poor general condition or a combination of both, do not qualify for inclusion in the successful category. It includes both fit and ill patients - those with positive sputum and those with negative sputum. For reasons of clarity, the course of the 20 patients in the group are recorded briefly below. In eight of the 20, thoracoplasty has been substituted for the extra-pleural collapse or is intended in the near future. Inadequate control of the disease was the reason on five occasions and twice a persistent effusion following clot removal was the cause. One of the patients with incomplete disease control has still to have her thoracoplasty and has been admitted for this purpose. The eighth patient required thoracoplasty when she developed a bronch-extraopleural fistula one year after her extra-pleural operation. At the present time only two stages of this thoracoplasty have been carried out but the patient is well and an ultimate successful outcome is in sight.

In a further three patients the extra-pleural pocket dwindled progressively and was ultimately lost. Inadequate and unskilled refilling was the cause in two of them and in the third a persistent effusion paved the way to final obliteration. Five other spaces were abandoned because of

superadded infection which was twice staphylococcal and on three occasions tuberculous. Two patients with initially inadequate spaces had unsuccessful oil conversion and one child of 12 years with incomplete disease control ultimately required resection of the affected lung. The twentieth patient still has air refills,but disease below the extra-pleural pocket and in the contra-lateral lung, is progressing steadily. The ultimate fate of these patients is recorded in Table No. 12.

TABLE NO. 12.

FATE OF SPACE.	NO.OF PATIENTS.	PRESENT CONDITION.
Maintained by Air Refills.	1	Deteriorating. Sputum positive.
Maintained by Oil.	2	One - Late death. One - Deteriorating.
Converted to Thoracoplasty.	8	Five - Completed and in excellent general condition. Sputum negative, etc. One - still to be carried out. One - still to be completed. One - completed and deteriorating.
Involuntarily abandoned.	3	All in very good condition. Sputum negative etc.
Voluntarily Abandoned: (a) Staphylococcal Empyema 2.		One - well. Negative sputum etc. One - deteriorating.
(b) Tuberculous Empyema 3.	5	All well and all negative.
Resection	1	Lung resected early November 1951. Child fairly well. Negative sputum.
TOTAL:	20	

Thirteen of these patients, therefore, have completed these alternative forms of treatment and are well with negative sputum. One is in process of completing her thoracoplasty for a broncho-extrapleural fistula and one has still to undergo thoracoplasty for a persistent cavity below the extra-pleural pocket. Only seven patients still produce tubercle bacilli in their sputum and this number includes the solitary death in this series.

C. Assessment of Results on Basis of Clinical Condition Irrespective of Extra-pleural Space.

On the basis of clinical condition, negative sputum etc., no fewer than 93 of the 100 patients are in a satisfactory state at the present time. Their mode of maintenance is shown in Table. 13.

TABLE NO.13.

METHOD OF TREATMENT.	NO.OF PATIENTS.	REMARKS.
Air refills continued.	72	Includes 5 bilateral cases and 1 tuberculous empyema maintained by air.
Oil conversion.	9	
Converted to Thoracoplasty.	5	
Extra-pleural pneumothorax abandoned without substitute.	4	Includes the 3 involuntarily abandoned and 1 obliterated tuberculous empyema space.
Extra-pleural pneumothorax abandoned and replaced by phrenic crush and pneumoperitoneum.	2	1 staphylococcal empyema. 1 tuberculous empyema.
Resection of incompletely controlled lung.	1	
TOTAL:	93	(93 per cent)

D. Clinical Facets of the Successful Case.

When a successful result has been achieved by extra-pleural pneumothorax, a very striking feature about those patients is the excellent general condition many of them achieve. Morale is high and they appear alert and fit. Many of them rapidly return to gainful employment and thus regain their self-respect and independence which is so liable to be lost when they contract tuberculosis with its multiple physical disabilities and its much less obvious, though probably more destructive, social stigmata. Thirty (30 per cent) had returned to work by October, 1951 and an equal number are rapidly approaching this state of fitness. They have become clerks, sales assistants, university students, factory hands, liftmen, etc. Many women have resumed their duties as housewives. The medical world is represented by a doctor, a nursing sister and several nurses. Outwith this employment group, several young women are contemplating early marriage - one of them has a bilateral collapse.

The physical examination of these patients is also interesting. By comparison with the high incidence of moist physical signs to be detected during routine thoracoplasty check-up, the respiratory murmur in the successful extra-pleural patient is devoid of adventitiae. As a result, cough and sputum are almost invariably absent. If a few crepitations are audible they are not resident in the lower lobe as after thoracoplasty, but rather in the middle lobe on

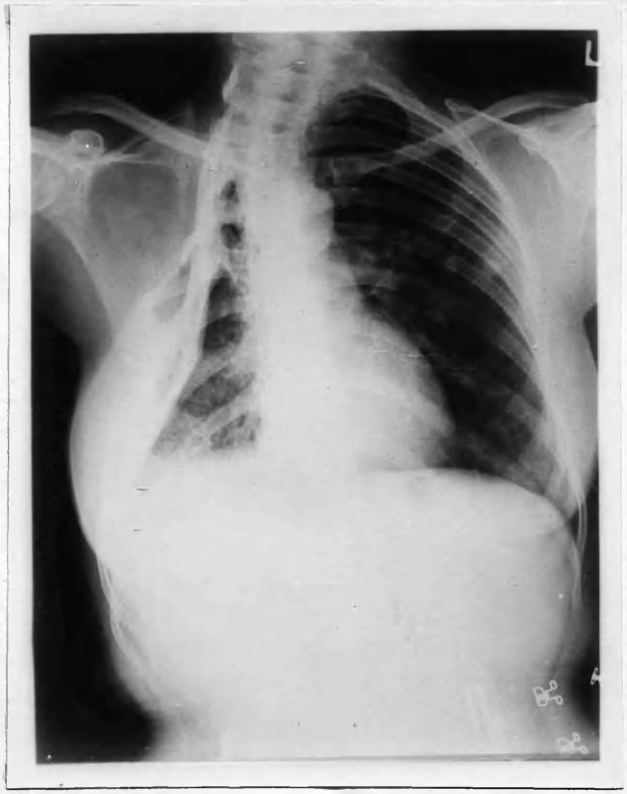


Fig.37.

Fig.38.

Fig.39.

Fig.40.

Fig.41.

the right and the lingula on the left. Even those stray crepitations, however, are more the exception than the rule, and are usually associated with little or no sputum. The post-thoracoplasty crepitations admittedly are probably due more to a bronchiectatic condition rather than to active tuberculosis. But assiduous examination of the sputum not infrequently produces the bacillus and a chronic tuberculous endobronchial infection remains a constant menace to both the patient and his associates. The extent of this bronchiectatic involvement is impossible to assess without the instillation of lipiodol into the bronchial tree. Postero-anterior radiography by itself may appear eminently satisfactory. Fig. 37. shows the radiological appearances of a woman who had an orthodox three stage thoracoplasty performed at Mearnskirk Hospital in 1947. The post-operative course was complicated by transitory total atelectasis which gradually cleared. The collapse achieved appears excellent until bronchograms are performed. (Fig.38. and 39.), and show the gross dilatation throughout the right bronchial tree with crowding of the basic bronchi. The bronchograms of a patient with an extra-pleural collapse (Figs. 40.and 41.) are reproduced for comparison. These latter photographs illustrate admirably the strictly localised control effected by extra-pleural pneumothorax. The limits of the space are well shown in both postero-anterior and lateral views. The right upper lobe is atelectatic and the bronchus to it is completely

occluded, preventing the entry of lipiodol to the lobe. The right middle and lower lobes by comparison appear completely undisturbed and all their bronchial subdivisions are adequately portrayed. These bronchi too, are all of normal calibre.

Routine vital capacity estimations were also carried out at the time of review, for comparison with the pre-operative values. The shortcomings of assessing respiratory function in this way are realised, but the figures do afford a crude guide. There were almost as many patients with an increased vital capacity as there were with a reduced reading. Several were completely unchanged. Over the whole series the average drop per patient amounted to only 40 cubic centimetres. Even from these crude figures it is obvious that extra-pleural pneumothorax is not a drastic reducer of respiratory capacity. Gaensler and Strieder (1950) have exhaustively investigated the effect of extra-pleural pneumothorax on pulmonary function. The methods they employed, included estimations of maximum breathing capacity, vital capacity, residual air, ventilation on exercise, breathing reserve and bronchospirometry. At the end of six months the loss in vital capacity was 12 per cent and there was an increase of two per cent in the maximum breathing capacity. They compared their values in extra-pleural pneumothorax with those obtained after thoracoplasty, pneumonectomy, lobectomy, intra-pleural pneumothorax and phrenic nerve interruption. Extra-pleural pneumothorax was

found to be the most function-preserving procedure of any of the methods of treatment studied.

In selectively compressing the diseased upper lobe, the pneumothorax leaves the function of the remainder of the lung largely indisturbed. The contention that this basal remnant continues satisfactory function is supported by the fact that one of our patients with bilaterally adequate extra-pleural collapses showed only a 500 cubic centimetre reduction in his vital capacity readings. Lung tissue largely defunctioned by tuberculous disease is no loss to the respiratory reserve of the patient and indeed its effective compression can contribute to improvement in respiratory capacity.

4. SUB-DIVISION OF RESULTS ACCORDING TO INITIAL STATE OF THE PATIENT AND COMPARISON OF RESULTS WITH THE LITERATURE.

In their authoritative review of extra-pleural pneumothorax up to 1940, Dolley and his colleagues adopt the classificiation described by Schmidt and Adelberger to classify the results in their personal series of 141 operations in 135 patients. They sub-divide the indications for operation into absolute, broad and conditional groups, according to the state of the patient. The criteria for the absolute category are:-

1. Intra-pleural pneumothorax must have been tried and found unsuccessful.

2. Cavities must not be fibrotic, stiff walled, or over four centimetres in diameter. The disease must not extend below the sixth rib posteriorly.
3. The contra-lateral lung must be free of active disease.
4. The lesions must be non-active, relatively recent, limited in extent and present in a patient who is a fair or good surgical risk.

In the broad group, cardio-respiratory function is only fair, the cavities are somewhat fibrotic or of considerable size and located at the lung periphery, the contra-lateral lung may be more or less extensively involved and the disease may be of long standing. The conditional group represents the dregs. Condition is poor, cavities are thick walled and the contra-lateral lung is also excavated.

At first glance such a sub-division is laudable, but in practice its main value lies in the retrospective assessment of results. It is useful to know that a patient fulfilling all the absolute requirements is likely to have a good prognosis but to the unfortunate patient who fails to qualify, a classification of narrow indications affords scant comfort. The problematical risks of the operation are to be weighed in many cases against almost certain death from progressive disease if left alone. Cutler (1951) stresses the necessity of being 'liberal with indications for surgery' in such circumstances and there can be little doubt that extra-pleural

pneumothorax, with its selective action and minimum of general and respiratory upset, is capable of much wider application than any other surgical form of treatment for pulmonary tuberculosis.

In addition, separation into the three categories described is not always easy. Quite an appreciable number of patients, by not fulfilling in minor degree one of the absolute criteria, e.g. early involvement of the contra-lateral lung, should be dropped logically to the broad group. Similarly minor defaulters from the broad class should descend to the conditional. Each downward step, however, represents to the writer a marked increase in the gravity of the illness and those borderline cases are frequently hardly ill enough to justify such a drop. Adhering, however, as closely as possible to this sub-division and retaining doubtful patients in the highest possible group, in this series there were 58 in the absolute class, 31 in the broad and 11 in the conditional. All the patients with absolute indications are alive and well with cavity closure and sputum conversion. Of the 31 members of the broad group 27 (87.1 per cent) had reached a similar state. Even the conditional patients have seven (63.5 per cent) of their number negative for tubercle bacilli and the chance of these poorest risk cases becoming arrested is surprisingly good. Their results certainly cannot be spoken of in terms of healed lungs but many of them are in the best clinical condition they have been in since the commencement of their

disease and some have prospects of achieving an ultimate return to lasting health. By very reason of the criteria which qualified them for the conditional group, many have lung damage of an irreversible character and the potentially temporary effect of the extra-pleural collapse may leave behind the problem of further treatment when refills of their spaces are abandoned. On the other hand there seems to be no valid reason why the air maintenance of the extra-pleural pneumothorax cannot be carried on indefinitely. Murstad (1951) expresses a similar opinion on the potential permanance of air refills. In addition if air proves unsuitable, oil may be substituted and the collapse may be persisted with indefinitely. Table No.14. records the condition of the space in the patients of each group.

TABLE NO.14.

FATE OF SPACE	CLASSIFICATION OF DISEASE AND PATIENT		
	ABSOLUTE	BROAD	CONDITIONAL
Air Refills	48 (82.7%)	19 (61.3%)	5 (45.4%)
Oil Replacement	5 (8.6%)	3 (9.7%)	3 (27.3%)
Conversion to Thoracoplasty	3 (5.2%)	5 (16.2%)	-
Voluntarily Abandoned:			
(a) Staphylococcal Empyema	- (0.0%)	1 (3.2%)	1 (9.1%)
(b) Tuberculous Empyema	- (0.0%)	2 (6.4%)	1 (9.1%)
Involuntarily Abandoned	2 (3.5%)	1 (3.2%)	-
Resection	-	-	1 (9.1%)
TOTAL = 100 patients.	58 (100%)	31 (100%)	11 (100%)

As can be seen the number of air filled spaces falls rapidly from the absolute via the broad group to the conditional group. The incidence of oleothorax, thoracoplasty and empyema all rise progressively in the same descending scale of fitness. By those space standards alone, the radically better prognosis in the absolute group is obvious.

Dolley (1940) in an analysed series of 100 patients had only 25 in the absolute category, 40 in the broad group and 35 with conditional indications. His comparable figures for sputum conversion and cavity closure are shown in Table No.15.

TABLE NO.15.

CATEGORY	DOLLEY ET AL (1940)	MEARNSKIRK (1951)
Absolute	100%	100%
Broad	70%	87.1%
Conditional	40%	63.5%

The marked improvement in the broad and conditional groups in this series is probably due in great part to the added benefit of the antibiotic cover afforded to our patients. . As can be seen, the prognosis in the absolute class is completely unchanged and with those optimum indications extra-pleural pneumothorax was an eminently suitable procedure even before the advent of streptomycin. Dolley goes on to review the results of all the principal exponents of the operation throughout the world. Based on the indications they

employed, he has divided them into two groups. The first group, including Alexander, Coryllos, Eloesser, Mayer, Nissen, etc. using extra-pleural pneumothorax as a stop-gap procedure in conditional patients had disastrous results. The death rate was high, the complications harassing and most of them at that time had largely abandoned the operation. In the second group were Brock, Graf, Maurer, Monod, Schmidt and Adelberger among others. Their patients were largely of the broad and absolute variety and of 1,545 operations performed by these men, 65 per cent of the patients were sputum negative and the fatality rate was 8 per cent.

Several other writers sub-divide their results according to the original clinical indications. Head et al (1948) use six indicating classes and classify their achievements accordingly. In their best group with moderately extensive bilateral infection, extra-pleural pneumothorax effected arrest of the disease in 87.5 per cent and only one died. With more advanced involvement and poorer general condition only 44.5 per cent achieved disease control. Sullivan (1948) with a follow-up period ranging from 18 months to eight years used the National Tuberculosis Association classification and found that with moderately advanced disease 44.1 per cent of his patients were in full time employment, whereas only 6.2 per cent of the very far advanced group were working. Four groups are described by Murstad (1951) and 96 per cent of the best risk cases obtained sputum reversal. Only two patients

died. No fewer than 15 per cent of the poorest group died and only 40 per cent of them contrived to get a satisfactory clinical and bacteriological result. His follow-up period ranged from one to eight years. Maurer (1938) divides his patients into those in whom thoracoplasty was impossible and those in whom thoracoplasty was possible but not desirable. In the former group 42 per cent attained a very good result by standards similar to those in this series. A further 28 per cent had good collapses but had occasional bacilli in the sputum. The possible thoracoplasty patients supplied 39 per cent good results and 30 per cent with sporadically positive sputum. Thus approximately two thirds of each group derived benefit from the operation. The overall follow-up for his series was six to 18 months.

Laird (1940) reported that 22 (61 per cent) of his 36 cases achieved a good end result and remarked that from his review of the literature this proportion was within the average range of from 55 to 65 per cent. His post-operative assessment period varied between nine months and two years and nine months. Roberts (1948) in an excellent review of 100 patients whose operations had been performed five to eight years previously found that 45 were dead, 46 were alive and well, including seven who had been converted to thoracoplasty and nine were alive with symptoms. He had 30 good risk patients with a history of less than two years and cavities less than three centimetres in maximum diameter. Of

this group five (16.7 per cent) were dead and 24 (80 per cent) were alive and well. In addition one other patient was alive with a post-thoracoplasty sinus. Air refills had been abandoned in all of these successful cases and yet only two had required thoracoplasty. Roberts, however, does not mention the fate of the collapsed lung or comment on its ability to re-expand after prolonged compression.

With part of his series in the antibiotic era, Cutler's (1951) results are of interest. Between 1938 and 1946 he performed 64 extra-pleural operations of which 36 (56.2 per cent) were successful, 12 (18.8 per cent) were unsuccessful and 16 (25 per cent) died from causes attributable to the actual operation. From 1947 to May 1950,65 extra-pleural pneumothoraces were carried out and 55 (84.6 per cent) were successful. Only nine (13.9 per cent) were rated unsuccessful and there was one operative fatality (1.5 per cent). These dramatically improved results from 1947 onwards he attributed to: (1) better selection of cases; (2) improved operative technique and (3) modern drug therapy. Elsewhere in his paper he accords full praise to the antiobiotics for effectively reducing the incidence of the hitherto harassing space complications and remarks on the vital difference they have made in extra-pleural surgery. Of his 91 successful cases, 68 (74.7 per cent) have spaces maintained by air refills and 16 (17.6 per cent) have been converted to oleothorax.

From perusal of the literature and from the experience derived from the cases in this series, there can be little doubt that with progressive narrowing of the indications and ruthless exclusion of border-line patients, the results of extra-pleural pneumothorax treatment can be spectacularly successful. With such restrictive practices the results of many doubtful procedures can be improved. In the sphere of pulmonary tuberculosis with these methods there is a danger too that some of the patients subjected to operation quite conceivably may have contrived ultimately to heal their disease without any extraneous intervention. (Brock 1938). To confine extra-pleural pneumothorax to the narrow limits of the ideal case is to deny many patients, otherwise unsuited for surgery, the chance of a happy recovery from their disease. It ignores also the magnitude of the problem which exists in a highly industrialised area such as Glasgow, where the incidence of tuberculous infection is high and where large numbers of patients with positive sputum must needs be maintained on an out-patient basis for lack of sanatorium beds. The boon of a widely applicable therapeutic measure capable of rapid turnover is obvious under such circumstances. On the basis of even the sputum conversion figures for the series, extra-pleural pneumothorax appears to be a form of treatment which meets those materialistic requirements. During 1951 no fewer than 115 pneumonolysis operations have been performed at Mearnskirk Hospital. When thoracoplasty was the sole major

surgical procedure for pulmonary tuberculosis, only 45 patients were passed through the unit for this operation in the peak year of 1949. This almost three to one advantage does not take into consideration the fact that the 115 extra-pleural pneumothoraces were not the only operations for pulmonary tuberculosis. A further 40 to 50 patients were treated by resection or thoracoplasty in almost equal numbers. The overall major surgical figure for the year was therefore in the vicinity of 160 patients.

Even with the quadrupled attack on the problem the surgical waiting lists have not reduced. Such is the measure of the wide applicability of extra-pleural pneumothorax. For every suitable candidate for thoracoplasty there would appear to be at least three to four amenable to extra-pleural surgery.

5. FATE OF SPACE AFTER CESSATION OF REFILLS.

The ultimate fate of the lung effectively compressed by extra-pleural pneumothorax over a considerable period of time remains a matter for some conjecture. The scope of this thesis is to assess the effects of the operation on patient and disease alike during the course of a relatively short follow-up. In none of the cases under consideration has the collapse been deliberately abandoned after such time as has been deemed requisite for the underlying disease to heal. Three spaces have inexorably dwindled in the face of

insufficient refills or effusion. In two of those patients the lungs have almost totally re-expanded and only a small cap of apical extra-pleural fluid persists. The third has a somewhat larger effusion which is none the less slowly absorbing and lung re-expansion is progressing quite satisfactorily. The longest period of collapse, however, is only 18 months and the state of the lung after an elected period of collapse of some three to four years requires some consideration.

Perusal of the various opinions expressed in the literature is somewhat confusing. Sullivan (1948) categorically states that extra-pleural pneumothorax is a permanent form of collapse. Only four (4.7 per cent) of his 92 cases have re-expanded lungs. Yet in 1946 Arnold and McNab state that the end results as far as they know seem little inferior to that of an abandoned intra-pleural pneumothorax. They had some patients with good expansion after years of collapse. Paxton et al (1940) hint at the choice of permanent extra-pleural collapse or thoracoplasty - after four years. The possibility of thoracoplasty to close some of the spaces is also suggested by Brock (1938). Reid (1946) reports that roughly two thirds of his spaces were obliterated at the end of four years and Proctor (1940) finds that the lung will re-expand to a greater or lesser extent after stopping refills as late as two to three years after operation. In the international survey made by Dolley and his colleagues in

1940, the consensus of opinion was that the end result would be either: (1) a permanent oleothorax or, (2) partial lung re-expansion with a small residual oleothorax or obliterative extra-pleural fibrosis with little likelihood of thoracoplasty.

With these divergent opinions it is essential to examine the requirements of collapse therapy in general. By and large it is applied to control unstable or advancing tuberculous disease which may ultimately kill the unfortunate patient. On the other hand it may be employed to rid the chronic but fairly well stabilised patient of cavities and infected sputum which are a menace to himself and his fellows. (Churchill 1940). In the former type of disease, measures such as artificial pneumothorax or phrenic crush associated with pneumoperitoneum may be applied, but even with those apparently simple and 'reversible' methods the later re-expanded lung may be quite considerable reduced in function. After late obliteration of an artificial intra-pleural pneumothorax, evidence of reduced function is frequently afforded by the late radiological appearances. The pleura is usually thickened, the hemithorax is contracted and its ribs are tiled, the costo-phrenic sulcus is frequently obliterated and movement of the mediastinum to the affected side is usually obvious. After simple phrenic crush an appreciable percentage of patients never recover diaphragmatic function and probably many more have only incomplete return of movement. Add to this the prolonged stretching effect

of pneumoperitoneum therapy on the diaphragm, and a more accurate assessment of these measures from the functional point of view is reached. In addition, in each the effect of the fibrosing disease on lung function must be taken into account. The overall effect of those factors, is a considerable reduction in the functional capacity of the apparently re-expanded lung. The irreversible action of thoracoplasty requires no comment.

Those late effects are the price of disease control and the price paid is usually in proportion to the original disease. It is not a high one when the lethal aspects of pulmonary tuberculosis are considered.

With extra-pleural pneumothorax collapse, therefore, an anatomical and functional re-expansion can hardly be expected. It would seem unlikely that the floor of the space composed of pleural tissues and thickened by prolonged exposure to high pressure air refills could relax sufficiently in a concentric manner to allow the lung to once more fill every part of the cupola of the thorax. This pleural floor in addition is attached continuously at its periphery to either chest wall or mediastinum. Re-expansion will probably therefore be only partial and as seen in our few re-expanded cases, fluid will fill the remaining space. The ultimate outcome is likely to be organisation of the effusion associated with gradual obliterative fibrosis. An almost identical opinion is put forward by Laird (1940). Incomplete expansion may

necessitate thoracoplasty in a few patients.

The final question concerns the duration of refills. It does not seem logical to compare the immediately effective, active compression collapse of extra-pleural pneumothorax with the more gradually applied relaxation effect of intra-pleural pneumothorax. The maintenance of the latter requires extension over many years to achieve an adequate control of the excavated lesion. The diseased tissues are passively relaxed, reduced in volume but not altogether freed from the continual rhythm of respiratory movement. At the end of the inter-refill period some quite considerable re-expansion may occur and the effect of this collapse is therefore in some ways intermittent. By comparison, the extra-pleural collapse, from the earliest post-operative days, produces high pressure compression of the disease focus. Apposition of cavity walls and closure of drainage bronchi are effected early and thereafter consistently and unremittingly maintained throughout treatment. The localized application of this effect is ensured by leaving the undiseased lung remnant in firm adherence to the chest wall. The immediate, persistent and forceful compression of disease should be able to procure more rapid healing than can the much less active, somewhat intermittent relaxation of intra-pleural pneumothorax.

The duration of extra-pleural refills, however, must still be measured in years. A fair estimate lies somewhere between two and three years, depending to some extent on the

gravity of the original disease. At the present time consideration is being given to the cessation of treatment of some of the earlier cases in this series and also of some of those maintained for 18 to 24 months whose initial disease was not advanced.

* * * * * * *

CHAPTER SIX.

CONCLUSIONS.

With the modern drug cover now available, the operation of extra-pleural pneumothorax is a safe and valuable addition to the surgical treatment of pulmonary tuberculosis. Of the previous, dangerous, post-operative complications, tuberculous and mixed infection of the extra-pleural space are drastically reduced in frequency, while bronchogenic spread of disease is almost entirely eliminated. In this series the fatality rate of the operation itself is nil.

The removal of those grave post-operative sequelae has correspondingly widened the scope of the operation. It is no longer dependent on the contra-indications of thoracoplasty but constitutes a definitive treatment of choice in itself over a wide range of tuberculous pathology. Its well tolerated reception at both extremes of the age scale and in patients in poor general condition, added to the fact that it can be applied successfully to both lungs, make it available to a much wider cross section of the tuberculous population than any other form of surgical treatment.

Extra-pleural pneumothorax is a one stage procedure capable of producing rapid, effective compression of a diseased upper lobe while leaving unimpeded the function of the unaffected remnant. This highly selective attack on the tuberculous process constitutes one of the most desirable

advantages of the operation. There is no unnecessary collapse of undiseased lung tissue. The one stage nature of the operation and its expeditious achievement of disease control contribute to a rapid turnover of patients. This is a very valuable materialistic benefit, particularly in a region such as Glasgow where in December, 1950, the tuberculous population numbered 10,342 (M.O.H. Report, City of Glasgow, 1950), and where the waiting time for surgical treatment of the disease varies between six and twelve months.

The excellent cosmetic results of the operation make it especially attractive for female patients but the absence of mutilation is equally valuable from the psychological viewpoint, for every patient irrespective of sex.

The ultimate fate of the extra-pleural space after the cessation of refills remains a matter of conjecture. At least partial re-expansion of the lung can be expected, while obliterative fibrosis deals with the remaining pocket. It would seem probable that only a small number of patients will require later active measures to close the space.

With the removal of the former post-operative complications the only remaining disadvantage of extra-pleural surgery is the necessity for skilled and prolonged post-operative management of the space. The patient must reside within easy reach of the experienced chest physician working in a satisfactorily equipped clinic, if his refills

are to be adequately and safely maintained. If desired this difficulty can, to a large extent, be overcome by the substitution of a vegetable or mineral oil as the space filling agent. Only periodic supervision is thereafter required. Finally the inconvenience of regular attendances for refills is more than counterbalanced by the opportunities for regular and frequent observation of the patient thus given to the chest physician.

* * * * * * *

LITERATURE.

Alexander, J. (1925). Surgery of Pulmonary Tuberculosis. 1st Edition. H. Kimpton, London.

Alley, F.H. (1946). Radiology. 46, 470.

Annotation. (1949). Lancet. 2, 707.

Arnold, M., and McNab, G.R. (1946). Tubercle. 27, 130.

Aycock, T.B., Brantigan, O.C., and Welch, H. (1940). J. Thorac. Surg. 9, 382.

Banyai, A.L. (1946). Pneumoperitoneum Treatment. C.V.Mosby Company, St. Louis. U.S.A.

Barrett, N.R. (1946). Personal Communication quoted by Reid, H. in Thorax (1946). 1, 211.

Bavin, E.M. (1949). J. Pharmacy and Pharmacol., 1, 790.

Benda, Descomps, and Le Foyer. (1948). Rev. de la Tuberc. 12, 532.

Berard, M., and Hermann, A. (1948a). Rev. de la Tuberc. 12, 398.

Berard, M., and Juttin, P. (1948b). Ibid. 12, 720.

Berard, M., and Juttin, P. (1948c). Ibid. 12, 721.

Berard, M., and Juttin, P. (1948d). Ibid. 12, 824.

Berard, M., and Grezard. (1949). Ibid. 13, 361.

Bignall, J.R., Clegg, J.W., Crofton, J.W., Smith, B.J.D., Holt, H.D., Mitchison, D.A., and Armitage, P. (1950). Brit. Med. J. 1, 1224.

Brock, R.C. (1938)	Brit. J. Tuberc. 32, 173.
Brunner, Von A. (1944).	Schweiz. Z. Tuberk. 1, 2.
Chapman, P.T., O'Brien, E.J., O'Rourke, P.V., and Douglas,B., (1949).	J. Thorac. Surg. 18, 15.
Christiansen, L.R. (1949).	J. Clin. Invest. 28, 163.
Churchill, E.D. (1940).	Am. Rev. Tuberc. 41, 423.
Cleland, W.P. (1948).	Thorax. 3, 127.
Climie, H. (1950).	Lancet. 2, 308.
Condon, W.B., and Harper, F. R. (1949).	Arch. Surg. Chicago. 59, 705.
Cutler, J.W. (1951).	J. Thorac. Surg. 21 217.
Davies, M.H. (1924).	Brit. Med. J. 2, 1145.
Davies, M.H. (1948).	Thorax. 3, 189.
Dempsey, T.G., and Logg, M.H. (1947).	Lancet, 2. 871.
Dolley, F.S., Jones, J.C., and Skillen, J. (1940).	Am. Rev. Tuberc. 41,403.
Duggeli, O. (1944).	Scweiz. Z. Tuberk. 1, 42.
Edison, A.O., Frost, B.M., Graessle, O.E., Hawkins,J.E., Kuna, S., Mushett, C.W., Silber, R.H., and Solotorovsky, M. (1948).	Am. Rev. Tuberc. 58, 487.
Feldman, W.H., Karlson, A.G., and Hinshaw, H.C. (1948).	Am. Rev. Tuberc. 58, 494.
Feldman, W.H., and Hinshaw, H.C. (1948).	Brit. Med. J. 1, 87.
Friedman, L.L., Davenport, L.O., Bohorfoush, J.C. (1949).	Dis. of Chest. 15, 306.
Gaensler, E.A., and Strieder, J.W. (1950).	J. Thorac. Surg. 20, 774.
Gaensler, E.A., and Strieder, J.W. (1951).	Am. Rev. Tuberc. 63, 547.

Garrand, R.M., (1948).	Rev. de la Tuberc. 12, 870.
Goodacre, C.L., and Seymour, D.E. (1949).	J. Pharmacy and Pharmacol. 1, 788.
Graessle, O.E., and Pietrowski, J.J. (1949).	J. Bact. 57, 459. (Abstract).
Graf, W. (1936).	Dtsch. Med. Wschr. 62, 632.
Graf, W. (1937).	Ibid. 63, 4.
Grigor, K.C. (1951).	Post-Operative Atelectasis. M.D. Thesis, University of Glasgow.
Hayes, E.W. (1949).	Dis. of Chest. 15. 720.
Head, J.R., and Moen, C.W. (1948).	Am. Rev. Tuberc. 57, 471.
Hinshaw, H.C., Feldman, W.H., Carr, D.T., and Brown, H.A. (1948).	Am. Rev. Tuberc. 58, 525.
Hobson, L.B., Tompsett, R., Muschenheim, C., and McDermott, W. (1948).	Am. Rev. Tuberc. 58, 501.
Hoffman, R., and Kettler, M. (1943).	Am. Rev. Tuberc. 47, 388.
Horne, N.W., and Wilson, W.M. (1949).	Lancet. 2, 507.
Hurni, H. (1949).	Schweiz. Z. Path. Bact. 12, 282. (Abstract).
Hurst, A., Grow, J.B., Perlmutter, H.M., and Levine, S. (1950).	J.A.M.A. 143, 286.
Ivanovics, G. (1949).	Proc. Soc. Exp. Biol. and Med. 70, 462.
Joly, H. (1948).	Rev. de la Tuberc. 12, 309.
Konstam, M. (1948).	Thorax. 3, 247.
Kropp, B.N. (1951).	J. Thorac. Surg. 21, 421.

Laird, R. (1940). Extra-pleural Pneumothorax. M.Ch. Thesis, University of Glasgow.

Le Foyer, P., and Larrand, G. (1948). Rev. de la Tuberc. 12, 735.

Lehmann, J. (1946). Lancet. 1, 15.

Lehmann, J. (1947). Rev. Gen. Sci. 54, 222. (Abstract).

Livingstone, R., and Street, E.W. (1951). Tubercle. 32, 8.

Madigan, D.G., Griffiths, L.L., Lynch, M.J.G., Bruce, R.A., Kay, S., and Brownlee, G. (1950). Lancet. 1, 239.

Maier, H.M., and Hurst, A. (1946). Am. Rev. Tuberc. 54, 509.

Marmet, A. (1949). Rev. de la Tuberc. 13, 358.

Maurer, A., Savitsch, E., and Denver, A.B. (1938). Lancet. 2, 1468.

Mayer, A. (1913). Dtsch. Med. Wschr. 11, 2347.

Medical Research Council. (1948). Brit. Med. Jour. 2, 769.

Medical Research Council. (1949). Ibid. 2, 1521.

Medical Research Council. (1950). Ibid. 2, 1073.

Mitchison, D.A. (1949). Lancet. 2, 694.

Moore, J.A., Murphy, J.D., and Elrod, P.D. (1949). J. Thorac. Surg. 18, 45.

Mullard, K. (1948). Thorax. 3, 233.

Mulvihill, D.A., Miscall, L., and Klopstock, R. (1949). J. Thorac. Surg. 18, 1.

Murstad, E. (1951). Lancet. 2, 299.

Nagley, M.M. (1949).	Practitioner. 163, 459.
Newton, H.F., Dawson, D., and Dunphy, J.C. (1940).	Am. Rev. Tuberc. 41, 319.
Nissen, R. (1931).	Surg. Gynec. Obstet. 52, 732.
Ottaviano, F. (1940).	Am. Rev. Tuberc. 41, 334.
Paxton, J.R., Churchill, A.S., and Skillen, J. (1940).	Am. Rev. Tuberc. 41, 163.
Pierre-Bourgeois and Lebel, M. (1938).	Pr. Med. 41, 818.
Proctor, O.S. (1940).	J. Thorac. Surg. 9, 392.
Read, C.T., and Berry, F.B. (1950).	J. Thorac. Surg. 20, 384.
Reid, H. (1946).	Thorax. 1, 211.
Report of M.O.H. of City of Glasgow. (1950).	
Report of Research Committee of British Tuberculosis Association. (1951).	Tubercle. 32, 217.
Rhodes, B. (1937).	Lancet. 2, 377.
Roberts, A.T.M. (1948).	Thorax. 3, 166.
Romanis, W.H.C., and Sellors, T.H. (1935).	Lancet. 1, 802.
Russo, J.G. (1943).	J. Thorac. Surg. 12, 316.
Samson, P.C. (1948).	Am. Rev. Tuberc. 58, 38.
Sauerbruch, F., and O'Shaughnessy, L. (1937).	Thoracic Surgery. Ist Edition. Edward Arnold and Co., London.
Schmidt, W., (1936).	Beitr. Klin. Tuberk. 88, 689.
Schmidt, W., (1938).	Ibid. 91, 121.
Seip, M. (1950).	Reported in J.A.M.A. 142, 905. From Acta Tuberc. Scandinav. (1949). Supp. 19, pp. 9 - 124.

Sellors, T.H. (1938).	Brit. J. Tuberc. 32, 173.
Semb, C. (1937).	Brit. Med. Jour. 2, 650.
Sherry, S., Tillett, W.S., and Read, C.T. (1950).	J. Thorac. Surg. 20, 393.
Simmonds, F.A.H., and Hounslow, A.G. (1941).	Tubercle, 22, 66.
Smart, E.P., Samson, P.C., and Childress, M.E. (1948).	Am. Rev. Tuberc. 58, 22.
Stoyko, N.G. (1946).	Tubercle. 26, 48.
Sullivan, H. (1948).	J. Thorac. Surg. 17, 38.
Tillett, W.S., and Garner, R. L. (1933).	J. Exp. Med. 58, 485.(Abstract).
Thomas, C.P., and Cleland, W.P. (1942).	Brit. J. Tuberc. 36, 109.
Thomson, L.W., and Janes, R.M. (1942).	Am. Rev. Tuberc. 45, 357.
Tuffier, T. (1891).	Sem. Med. B. Air. 11, 202. Quoted by Wilson, D.A. (1948), in J. Thorac. Surg. 17, 111.
Tuffier, T. (1914).	Etat actuel de la chirurgie intrathoracique. Masson et Cie. Paris. Quoted by Alexander J. (1925).
Turner, G.G. (1943).	Modern Operative Surgery. 3rd Edition. Vol.I. Cassell and Company, London.
Waksman, S.A., and Schatz, A. (1945).	J. Amer. Pharm. Ass. Scientific Edition. 34, 273.
Wilhelmi, E. (1950).	Schweiz. Med. Wschr. 80, 82 and 107. (Abstract).
Wilson, D.A. (1948).	J. Thorac. Surg. 17, 111.
Zorini, A.O. (1949).	J. Internat. de Chir. du Thorax. 1, 137.

* * * * * * *